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## ABSTRACT

This publication contains abstracts of papers presented at the 53rd annual meeting of the National Association for Research in Science Teaching (NARST), held in Boston, Massachusetts, April 11-13, 1980. Papers relate to research techniques, learning, cognitive development, instruction, science curriculum, teacher education (preservice, inservice) and other topics. (FB)

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NATIONAL ASSOCIATION  
FOR RESEARCH IN SCIENCE TEACHING

53RD ANNUAL MEETING  
ABSTRACTS OF PRESENTED PAPERS

The Boston Park Plaza  
Boston, MA 02117  
April 11-13, 1980

**ERIC** Clearinghouse for Science, Mathematics  
and Environmental Education  
The Ohio State University  
College of Education  
1200 Chambers Road, Third Floor  
Columbus, Ohio 43212

SE 029679



## PREFACE

The ERIC Clearinghouse for Science, Mathematics, and Environmental Education has cooperated with the National Association for Research in Science Teaching to provide abstracts of most of the papers presented at the annual conference in Boston, Massachusetts, April 11 to 13, 1980.

All persons who had papers or symposia accepted were invited to submit abstracts for inclusion in this publication. Some editing was done by the ERIC staff to provide a general format for the abstracts. Special recognition should be given to Dr. Stanley Helgeson and the NARST Program Committee who obtained the abstracts and organized the program.

Many of the papers will be published in journals or be made available through the ERIC system. These will be announced through Resources in Education, Current Index to Journals in Education and other publications of the ERIC system.

Arthur L. White  
Editor



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## CONCURRENT SESSION A and B

### Session A-1 and B-1      Techniques and Procedures of Research

Topic:                      Applying and Interpreting the Results  
                                 of Meta-Analysis Procedures

Russell H. Yeany, Jr.

University of Georgia  
Athens, GA 30602

Recently, statistical analysis techniques for condensing and synthesizing the results of a large set of empirical studies into an interpretable form have been developed (Glass, 1978). These procedures have been labeled as meta-analysis and are quickly gaining favor as a means of making sense of the varied results usually present when one examines numerous studies on a single topic. Meta-analysis techniques can be grouped into two families. One is employed primarily for experimental studies where treatment "effect sizes" are calculated and analyzed. The second is used to synthesize the results of correlational studies. In the latter case, "correlation coefficient conversions" are calculated and synthesized into mean correlation values. Both procedures are applicable to large bodies of accumulated science education research. The purpose of this proposed training session is to acquaint NARST members with the procedures, to assist them in interpreting the results of published meta-analyses, and to facilitate the acquisition of the skills required to conduct the two types of meta-analysis.

### References

- Glass, G. V   Integrating findings: The meta-analysis of research.  
In Shulman, L. (Ed.). Review of Research in Education. Itasca,  
Illinois: Peacock Publishing, 1978.

In this chapter, Glass expanded and more thoroughly  
presented meta-analysis procedures.

## RESEARCH APPROACHES FOR ASSESSING ENERGY

### EDUCATION ISSUES

Helen Loughner  
Gabriel M. Ziccarelli  
George A. Lednew  
David Carbonara

University of Pittsburgh  
Pittsburgh, PA 15260

This will be a symposium on research methodology with emphasis on new approaches for obtaining and analyzing information in making decisions for developing energy education curricula. It can be argued that, unlike the Post-Sputnik science curriculum movement, there are different forces influencing energy education curriculum movement, evaluation, and subsequent implementation. An aim of this symposium is to characterize these forces, as manageable data, and to demonstrate innovative research techniques for obtaining direction in approaches to decision making.

The panel of four researchers for this symposium has developed innovative approaches to investigating, collecting and analyzing data on the topic. These will be demonstrated with a data bank of over 700 variables for the social environment, family background, dogmatism, mental development, leisure interests and pursuits, intellectual ability, achievement, verbal and figural scientific reasoning ability, energy concept learning ability, and information processing capacity of senior high students from schools of two different demographic districts. These data are of a longitudinal study for measuring changes of opinions toward energy situations occurring in the past two years.

There is evidence that forced-choice polls on social issues inadequately measure opinion. Face-value verbal statements are known to have greater validity in expressing opinions but heretofore could not be treated because of limited computer capacities. Character-string programs for obtaining frequency traits of words used in opinion statements will be described in the symposium.

The same string techniques are used in measuring frequencies of key terms in newspaper and magazine reports on energy events occurring at the time that students expressed their opinions of the problem. A trend analysis model for weighting these opinion measures will be described by the panel.

The student opinion statements and those of media reports are treated with a model for quantifying the sequential structure of key words and all the words of passages. Analyses obtained from multidimensional scaling of these data and those of frequencies of the statement words will be presented.

The results of these innovative methodologies will be presented as outcomes of hierarchical, taxonomic, factor and discriminant analyses.



## THE IMAGE OF THE SCIENTIST -- REVISITED

Joseph G. Krajkovich

Edison Township Public Schools  
Edison, NJ 08817

In 1956, the American Association for the Advancement of Science (AAAS) conducted a nationwide survey in order to determine the image of science and scientists as held by secondary school students (Mead and Metraux, 1957). What they found was quite disturbing. Although there were positive things to be said, the students' image of scientists was stereotyped and rather negative, particularly when personalized as in a career or marriage.

The timing of the Mead and Metraux study was of particular interest since it just preceded the science curriculum "boom." One of the often repeated objectives of the inquiry-type curricula was to nurture a positive attitude toward science. The question raised, therefore, was -- Did the twenty year period since the AAAS study affect the science attitudes of secondary school students?

Six hundred eighty-three subjects participated in the study. Twenty-five subjects were interviewed, 188 submitted written narratives and 470 students (7th to 12th grades) completed the Image of Science and Scientists Scale (Krajkovich, 1978).

The results indicate that students today respond similarly to inquiries concerning the image of the scientists. The same ambiguity remained, in that, on one hand scientists were thought to be intelligent, hard working and humanitarian but at the same time they worked in jobs that were dangerous, tedious and time consuming. Furthermore, the vast majority of students neither wanted to be a scientist nor marry one.

Further similarities were uncovered when responses were analyzed according to gender. There was no significant difference between males and females in their overall attitude toward science as measured by the Image of Science and Scientists Scale. However, an item analysis indicated that females answered items with humanistic overtones more positively, and males answered items that referred to the adventure of science more positively. This is also consistent with the findings of Mead and Metraux.

#### References

Krajovich, J. G. The development of a science attitude instrument and an examination of the relationships among science attitude, field-dependence and science achievement. Unpublished doctoral dissertation, Rutgers University, 1978.

Mead, M. and Metraux, R. Image of the scientist among high school students. Science, August, 1957, 126, 385-390.

AN INVESTIGATION OF THE RELATIONSHIPS BETWEEN  
STUDENTS' DEGREE OF OPENMINDEDNESS AND THEIR  
PERFORMANCE IN MENTAL OPERATIONS

Pastor R. Rojas  
Ninoska R. Rojas

University of Pittsburgh  
Pittsburgh, PA 15213

Science teaching objectives related to major social problems, such as environmental education, have been incorporated into the regular school curriculum in an attempt to cope with ecological crises. The emphasis in this endeavor has been placed mainly in cognitive aspects of scientific issues related to the environment, and little attention has been paid to the students' affective domain, their systems of values and beliefs, which direct their desires and work. The affective domain has also been neglected when diagnosing for the assignment of science subjects to students.

Dogmatism, or degree of openmindedness, is one of the aspects of the affective domain that may have influence on the attitude of students toward science instruction related to major social problems. In the study of dogmatism, no significant relationship has been found with mental ability. The relationship between scores from the American Council on Education and the Dogmatism D-Scale scores, have been found to be essentially zero by Christensen (1963); this finding supported Rokeach's contention (1960) that intelligence and dogmatism are not correlated. Jackson and Strattner (1964) reported that dogmatism and retentive learning are negatively correlated. Research with high school students, grade levels seventh through twelfth, has produced slight negative correlation between education-age and dogmatism.

This investigation was to explore the influences that the degree of openmindedness may have in the mental maturation of students as an effort to find an approach that could lead to a better understanding of the maturational process, in order to plan and conduct science instruction.

Data were collected from a sample of 188 students, grade levels seventh and eighth (mean age 14.2) living in the suburbs of Pittsburgh, Pennsylvania. Students were given the forty item E-form of Rokeach's Dogmatism Scale (1960), the Piagetian type battery (Moser, 1975), and the Shipley test on abstract reasoning (1940). Total scores and subscores for mental operations (seriation, correspondence, reversitivity, transitivity, class inclusion, add-subtract, transformation, horizontal classification, and multiple classification) were developed from Shipley's test, and from the Piagetian type battery. From the E-Form a total score was developed, and also subscores for the categories established by Rokeach.

For the statistical analysis, the BMDP1M, Cluster Analysis, and the BMDP2R, Stepwise Regression, programs from the UCLA Health Sciences Computing Facility (Dixon, 1975) were used.

The major findings were:

- 1) Degree of openmindedness is negatively correlated ( $-0.3231$ ;  $p \leq .01$ ) with Piaget's total scores, and positively correlated ( $0.3056$ ;  $p \leq .01$ ) with Shipley's total scores.
- 2) Transitivity (Shipley), seriation (Piaget), horizontal classification (P), and multiple classification (P), accounted for 44.94% of the variance of total dogmatism score in the regression model;  $F = 33.57$ ; and  $DF = 4/183$ .
- 3) Transformation (S), seriation (P), horizontal classification (P), and multiple classification, accounted for 64.22% of the variance of the subscore "tendency to make a part line change";  $F = 88.12$ ;  $DF = 4/183$ .
- 4) Seriation (S), seriation (P), correspondence (P), transitivity (P), class inclusion (P), transformation (P), and multiple classification (P), accounted for 72.65% of the variance of the subscore "change in peripheral beliefs following a change in intermediate beliefs";  $F = 68.32$ ;  $DF = 7/180$ .
- 5) Seriation (P), correspondence (P), transitivity (P), and multiple classification (P), accounted for 33.60% of the variance of the subscore "attitude toward the past, present, and future";  $F = 23.15$ ;  $DF = 4/183$ .
- 6) Multiple classification (S), seriation (P), horizontal classification (P), and multiple classification (P) accounted for 48.71% of the variance of the subscore "knowing the future";  $F = 43.44$ ;  $DF = 4/183$ .

Values for the correlations of the mental operations in the regression equations, were always significant at the .01 level.

The discovery that dogmatism total score and subscores can be predicted from performance in mental operation, is an important contribution for the diagnosis of students difficulties in their maturation process, for the understanding of students' affective domain, and for the planning and conduction of science instruction.

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A PROJECT TO SURVEY AND PROMOTE ELEMENTARY  
SCIENCE INSTRUCTION IN NORTH CAROLINA

Charles R. Coble

East Carolina University  
Greenville, NC 27834

Dale R. Rice

Fayetteville State University  
Fayetteville, NC 27945

Rationale for the Study

A comprehensive National Survey of Science, Mathematics and Social Studies Education (Weiss, 1978) found that the dissemination of information concerning the new curriculum projects in science initially funded and supported by the National Science Foundation has not been highly successful. Many common factors were found to be serious barriers to affective science instruction. In addition, the time spent teaching elementary science was low. Although the report by Weiss provides much useful and somewhat alarming information about elementary science instruction across the nation, detailed information concerning individual statewide elementary science teaching practices and information needs to be surveyed and disseminated.

To meet this need in North Carolina, an information dissemination and survey study project was designed to:

- 1) inform key science personnel about the various options and teaching methodologies and research available in elementary science instruction;
- 2) survey local key personnel concerning elementary science instruction; and,
- 3) survey inservice teachers concerning elementary science instruction.

Methodology and Design

North Carolina has 145 local educational agencies (LEAs) contained within eight regions of the state. Each LEA is served by educational personnel in the regional education center.

Project staff traveled across the state to each regional educational center and put on a two-day Awareness Conference to inform key science personnel from each LEA within the region about elementary science instruction. Administrative and teacher questionnaires were distributed at each conference. Administrators filled out the questionnaire at the conference and then passed out the teacher questionnaires to two elementary teachers in each LEA following the conference. A follow-up conference was then held to assess the results and offer suggestions for the improvement of elementary science instruction in North Carolina.

#### Instruments and Data

The questionnaire developed for the survey was aimed at assessing the common practices, problems and areas of difficulty faced by teachers of elementary science in North Carolina. The 64 item questionnaire was analyzed by rank ordering areas of difficulty and most common teaching practices. Amount of time spent teaching science was the average time indicated by all returned questionnaires. Percentages were used to determine type of program in use and grade level taught. Responses were analyzed and computed for each educational region and then totaled to obtain statewide results.

#### Results and Conclusions

The survey represented the most indepth study in elementary science instruction ever undertaken in the state of North Carolina. During the eighteen month project a total of 891 teachers and 142 administrators from the eight educational regions responded to the questionnaire. The lack of supplies and equipment, insufficient funds, inadequate room facilities and textbook too difficult for students were the leading factors affecting the teaching of elementary science. Lecture/discussion was the most prominent means of teaching with over 85% of the teachers using a textbook to teach science. A more detailed report of the results of the project can be obtained by writing the authors.

The follow-up conference of leading science educators of the state formulated a comprehensive list of needed changes and proposed new directions for elementary science instruction in North Carolina for the decade of the '80's.

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CONCURRENT SESSION A and B

Session A-4 and B-4 Techniques and Procedures of Research

Topic: A Quantitative Procedure for Treatment Verification  
in Science

William H. Leonard

University of Nebraska  
Lincoln, NE 68588

Lawrence F. Lowery

University of California  
Berkeley, CA 95720

This session will train participants in the use of a procedure to verify if there has actually been statistically significant differences between two teaching methods as a means for arguing that the difference in methods was actually responsible for experimental differences in student achievement. Participants will process actual data and reach and discuss their own conclusions.

THE RELATIONSHIP OF COGNITIVE LEVEL FUNCTIONING  
IN ELEMENTARY PRESERVICE TEACHERS AND  
CLASSROOM SCIENCE TEACHING BEHAVIOR

Dennis W. Sunal  
Cynthia S. Sunal

West Virginia University  
Morgantown, WV 26506

Teacher functioning has assumed an important role in attempts to create more effective learning in students. Role expectations for successful classroom science teaching involves many complex behaviors which necessitate effective use of higher level thought processes and decision-making abilities. These include postulating hypothetical relationships between student classroom and teacher variables, manipulating propositions involving effective learning environments and making inferences about covert social-psychological processes. Professional teacher education programs have generally assumed that these behaviors are met through courses, classroom experiences and inservice requirements. Based upon research in the area of life-long development of cognitive functioning, the validity of this assumption should be questioned. This research indicates that only about one-half of adults attempting entry into, or are now involved in, professional education have developed the necessary high level thinking processes requisite for the performance of many professional role behaviors.

The purpose of the study was to establish the extent these effects, the ability to use higher level thought processes, may have on the variety and level of perception, performance and analysis of classroom science teaching behaviors. Postulating that general and specific mental structures were related to certain science teaching behaviors, the study compared classroom performance in the teaching of a short science unit by preservice elementary and middle (K-8 certified) grade teachers of differing levels of cognitive development.



Formal thinking abilities were assessed with a group test of formal reasoning and with individual interviews using Piaget's tasks involving combinatorial logic, hypothetical reasoning, and analysis and use of variables. An alternative hypothesis involving the appearance of formal thought in the area of professional training at an earlier time than indicated on traditional Piagetian tasks was tested using a group test involving analysis of critical classroom incidents as shown on a video tape. Science teaching behaviors were assessed using observational rating instruments of instructional planning and behaviors, validated and published in previous research studies on science teaching, and questionnaire and analysis reports of expectations and perceptions. Other variables measured included interests and attitudes toward teaching, teacher characteristics and ratings of the supportive aspects of cooperating teachers and classroom settings.

The sample, drawn from 330 senior level preservice education students at two large eastern universities, was comprised of 84 females and 12 males whose median age was 22. These preservice teachers were participating in field oriented programs involving a minimum of three semesters of extended observation and teaching in classrooms. Observations were made of general and specific science lesson assignments in order to increase experimental validity. Reliability of teaching behavior measures was checked through use on multiple occasions and use of multiple observers. Precautions were also taken to insure reliability in the Piagetian measures.

Data obtained from the measures were analyzed using analysis of covariance and regression analysis. The results did not support hypotheses concerning instructional planning and perception of behaviors involved in teaching classroom science and the development of general or specific mental structures. The data supported the hypothesized relationships between the observed classroom science teaching behaviors and resulting analysis of science lessons and the development of general and specific thought structures. The results have important implications in the design of preservice teacher education programs and further research into the development of science curricula used by teachers and inservice staff development activities.



PROBLEM SOLVING STRATEGIES OF  
HIGH SCHOOL CHEMISTRY STUDENTS

Dorothy Gabel  
Robert Sherwood  
Larry Enochs

Indiana University  
Bloomington, IN 47405

One of the basic skills required of high school chemistry students is problem solving. Chemistry teachers are well aware that many students lack proficiency in this area but are not cognizant of reasons why students are unable to acquire the skill. The purpose of this research, which is part of a study supported by NSF, is to compare through the use of interviews, the problem solving strategies used by high school chemistry students that are successful and unsuccessful in solving chemistry problems. Comparisons of strategies used by students of different verbal/visual preferences and different proportional reasoning skills are also made.

The subjects of this study were 560 high school chemistry students of nine schools in central and southcentral Indiana. Students were randomly assigned to one of four different methods used in teaching problem solving: factor label method, proportionality, analogies, and schematic diagrams. Using programmed booklets incorporating the above strategies, students studied four different units: the mole concept, stoichiometry, the gas laws, and solutions. From quizzes given during the units, students were classified as successful or unsuccessful problem solvers. These students then formed the pool from which 250 students of different verbal/visual preference and proportional reasoning ability were selected for interviews.

There were three purposes for conducting the interviews. These were:

- (1) to compare general problem solving strategies used by successful and unsuccessful students
- (2) to determine if students of different verbal/visual preferences and varying levels of proportional reasoning ability used different techniques, and
- (3) to determine whether any of the four methods taught was more successful than the others.

Interviews which were conducted after each of the four units used a "thinking aloud" technique in which students were given a problem and asked to solve it aloud during which time they were taped. Tapes were later analyzed using a coding sheet that examined the following: reading/organizing, recall, production, strategy, structural errors, evaluation, execution errors, and comments about the solution.

Prior to study of the chemistry units, students were classified as having verbal or visual preferences using a modified Individual Differences Questionnaire first developed by Paivio (1971). Reliability using the KR-20 method was found to be .77. Proportional reasoning ability was measured using a modified form of an instrument developed by Staver (1978). Reliability using the KR-20 method was found to be .86.

Comparisons between successful and unsuccessful students according to visual/verbal preferences, high and low proportional reasoning skills, and method used in instruction, were made using non-parametric statistical techniques, specifically, Pearson's Chi-Square Test of Homogeneity of Distributions (Marascuilo and McSweeney, 1977). These results and other insights gleaned from the interviews will be presented.

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THE USE OF ANALOGIES TO FACILITATE  
RULE USING IN ELECTRICAL SCIENCE

Ronald Jay Pollard

Florida State University  
Tallahassee, FL 32308

Analogies have been used since Aristotle for rendering unfamiliar ideas more comprehensible. Many claims in the philosophical literature about the ability of analogies to facilitate learning have been made; however, very few empirical studies have been conducted to substantiate them. The possible benefits in using analogies to teach abstract ideas is suggested by current research in science education.

Cantu & Herron (1978) maintain that many high school students have difficulty in learning abstract concepts and rules in physical science because they are unable to deal with rule and concept attributes that are not perceptible. The authors believe that comprehension can be improved when abstract attributes are made observable. Several authors have developed training programs that teach students to perform some formal operations through the manipulation of physical objects having perceptible attributes (McKinnon & Renner, 1971; Towler & Wheatley, 1971). Almy (1966) found that concrete-operational learners rely on imagery to manipulate the elements of a problem by forming images of what the solution would look like if certain physical operations were to be performed. Analogies have been shown to involve the manipulation of problem elements via imagery (Driestadt, 1968; Khatena, 1973) and, therefore, analogies may be useful in helping concrete-operational learners to perform some formal operations and to comprehend abstract ideas. The purpose of the present investigation was to determine how analogies could effectively be used in science instruction to facilitate the student's acquisition of abstract electrical rules.

A two-part study was conducted to test the hypothesis that the effectiveness of an analogy is dependent upon the complexity of its attributes. Analogy complexity was defined as the subset of attributes that students could reliably be expected to interpret from an analogy.

In the first part, a technique for constructing analogies and for judging their complexity was developed. Ten analogies were constructed and subsequently judged by six science writers. Two analogies differing in complexity were selected and incorporated into a unit of electrical science instruction. Three versions of the instructional text were produced:

- (a) no-analogy,
- (b) high-complexity analogy, and
- (c) low-complexity analogy

In the second part, one hundred twenty-nine high school physics students were randomly assigned to one of the three treatments (versions). Students were presented with a brief text on electrical rules. A short-answer posttest measuring rule-using served as the dependent measure. Significant total test scores were found between the two analogy groups and between the high-complexity analogy and the no-analogy groups. There were no significant differences between the low-analogy and no-analogy groups.

The results support the hypothesis that the facilitative effect of an analogy is a function of its attribute complexity. The results have implications for how analogies should be used in instruction. Typically, students are assumed to interpret an analogy in the same way that the teacher or science author does. The analogy is assumed to contain ideas familiar to the student and relevant to the concepts being taught. This study illustrates the need for educators to exercise caution in assuming that an analogy will be valid and understood by all students.

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## SELECTIVE ATTENTION EFFECTS OF TEXTBOOK STUDY QUESTIONS

William G. Holliday

University of Calgary  
Calgary, Canada T2N 1N2

Textbook questions remain the most prevalent study aid used to help students selectively attend to criterial information contained in science learning materials (Holliday, 1979). Yet, Markle and Capie's (1976) mathemagenic experiment and Wilson and Koran's (1976) analysis of this line of research represent the few competent attempts in science education to increase our understanding about how learners react to various question types adjunct to specialized learning materials in science. The present study draws on such mathemagenic work and generalizes to textbook study questions (i.e., usually found at the end of book chapters) in which students are permitted to review criterial material, as cogently justified and recommended by Faw and Waller (1976).

A cognitive process model, selective attention, was used to predict the results of the present study and used by others to explain mathemagenic and "nonmathemagenic" research findings also dealing with questioning behavior (Anderson, 1970; Wittrock & Lumsdaine, 1977). In part, this model predicts that students often fail to learn simple conceptual relationships when they are not forced to search instructional material for queried conceptual associations. One way of not forcing students to search the material and focus attention on criterial information is to overprompt learners by providing them with strong hints to answers -- a theoretically dysfunctional technique still used by an alarming number of teachers (Anderson, 1970; and Anderson and Biddle, 1975). Anderson and Faust (1967) supported this prediction in an experiment using a Russian vocabulary, self-paced program. Indeed, the purpose of the present study was to evaluate the generalizability of these results to a specialized science medium in terms of selective attention. Specifically, a question and no-question treatment were hypothesized to be more effective than a cued- (strongly prompted) question treatment which, in turn, was hypothesized to be more effective than a control (placebo).



### Methodology, Design and Instruments

The sample consisted of 171 (English-speaking, middle-class) high school biology students (14 to 16 years of age). Students were randomly assigned to three treatments and a single control followed by a 30-item, multiple-choice test, thus creating a posttest-only equivalent-group design. The three treatment groups were provided with specialized learning material, a picture-word diagram describing biogeochemical cycles.

The question-treatment group received the diagram and 20 textbook study questions. The cued-question treatment received the same questions and diagram with added prompts (not information) displayed in the diagram. The no-question treatment group received just the diagram. Finally, the control group read a science placebo passage.

The diagram used in this study described scientific pathways and cyclic scheme. Previous research (Holliday, 1976; Holliday, Brunner and Donais, 1977) has shown that this diagram can be effectively used with adjunct questions and can be used as a basis for generating operationally definable comprehension study and posttest questions (cf. Anderson, 1972). Indeed, such questions and relationships were developed for this experiment.

### Results and Conclusions

As predicted, the hypothesized ordering of treatments and control groups significantly differed ( $p \leq .05$ ) with one exception, as evidenced by an overall analysis of variance test followed by a Newman-Keuls multiple range test. The no-question treatment group did not significantly outperform the cued-question treatment group. Otherwise, these findings were anticipated and consistent with previously cited research and the selective attention process model.

Apparently, cuing students to queried information can reduce a student's need to search and comprehend simple conceptual relationships contained in such a diagram.

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A DEVELOPMENTAL COMPARISON OF THE EFFECTIVENESS  
OF STUDY GUIDE QUESTIONS IN DEPTH OF PROCESSING

Sandra Kirk  
Paul Eggen

University of North Florida  
Jacksonville, FL 32216

Donald Kauchak

University of Utah  
Salt Lake City, UT 84112

Objective

The purpose of this developmental study was to investigate the effects of study guide questions in different forms on the learning of science content from written text. Developmental comparisons were made by administering the study to fourth, seventh, and tenth graders.

Rationale

Study guides in the form of questions are often used to aid student progress through science text materials but variables determining effectiveness are largely unmeasured. Further, while the use of study guides is common at all levels it is not known if their effectiveness varies for different age levels of students.

Studies have shown that higher level questions produced better scores on an evaluation level posttest without a decrement in knowledge level performance. In particular, one showed that subjects producing their own examples of a principle scored higher than a control and recall condition (Watts & Anderson, 1971). Verbal learning research supports these findings, with "deeper levels of processing" characterized by semantic rather than orthographic processing resulting in greater retention scores (Craig & Lockhart, 1972).

The present study investigated both these areas by providing study guide questions requiring different levels of processing for students at different developmental levels.

### Method and Design

Subjects were randomly assigned to four treatment groups. Each was given a passage from a weekly science newsletter. The four experimental groups were given study guides with eight verbatim (V), true/false (TF), paraphrased (P), or open ended (OE) questions respectively. Half the student study guides referred to the paragraph number where the answer for each question could be found. (structured condition). The result was a 4 X 2 factorial design. The study was replicated with fourth graders (N = 85), seventh graders (N = 98), and tenth graders (N = 90).

### Instruments

A posttest consisting of two parts was prepared. The first subtest had eight questions identical to the verbatim questions (target questions) in the study guide, and the second subtest had twelve incidental questions which covered the content of the science passage but were unrelated to the study guide questions. The Kuder-Richardson 21 reliability for the posttest was .79.

### Results

In each replication a two way analysis of variance was used to determine if differences existed among groups on total scores, and the verbatim and incidental subtests. For fourth graders on total scores and for both subtests, two way interactions were found to be significant. For the unstructured condition total scores for TF Ss were significantly higher than both V and OE; on the verbatim subtest TF Ss scored significantly higher than V; and on the incidental subtest TF Ss scored significantly higher than all other groups. There were no significant differences between groups on the structured condition. For V, OE, and P groups the unstructured was significantly higher than the structured condition.

For seventh graders no interactions were significant. When comparisons by structure were made no significant differences among groups were found for the structured condition. For the unstructured condition the verbatim group scored significantly higher than the paraphrase group on total scores. Comparisons by treatment showed the OE group was significantly better with structure than with no structure on target questions, and the verbatim group was better with no structure than with structure on total scores.

For tenth graders no interactions were significant. Comparisons by structure showed no significant differences among groups for the structured condition. For the unstructured condition the true/false group scored significantly higher than the verbatim group on total scores. Comparisons by treatment showed that for the true/false group no structure was significantly better than structure on total scores. No other differences were found.



### Discussion

The results raise questions about the advisability of identifying answer locations in study guides. When comparisons by structure were made, the general trend was for no differences among groups on the structured condition for all three replications. This suggests that locating the answers essentially neutralized the treatment effects.

Another interesting trend was found. In general the condition requiring the most processing resulted in highest posttest scores. This was indicated in fourth grade where V unstructured scores were higher than V structured, and unstructured TF were higher than the other treatment groups in general. For tenth graders the TF group scored higher than the V group in the unstructured condition, and TF unstructured was higher than TF structured. In each case, the group scoring highest required more thorough processing (TF Ss had to ascertain the veracity of the statement and unstructured requires more processing or searching than structured). Additional investigation carefully measuring the effects of different types of questions is required before firm conclusions can be made.

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FACTORS INFLUENCING SCIENCE LEARNING:  
THE MODEL AND METHODOLOGY FOR RESEARCH

Herbert J. Walberg

University of Illinois at Chicago Circle  
Chicago, IL 60680

A chief purpose of educational institutions as a service industry is to produce learning. General educational research shows that there are production factors that are consistent positive correlates of learning and often substantial correlates as well. Student learning in science as well as many other subjects in the curriculum appears to depend on eight factors: student ability; motivation, and age or developmental level; instructional quality and quantity; and the social-psychological stimulation of home, peer and classroom environments. Although randomized experimentation with selected factors permits causal inference and estimates of learning returns to the production factors, experiments are difficult to execute in natural settings. Thus, the investigation of all eight factors simultaneously and the use of multivariate statistical methods particularly econometric regression analysis offer practical means for increasing the effectiveness and efficiency of science education.

Before launching large-scale research of this comprehensive kind, it is important to assess carefully the relation of each production factor to learning both in general as well as specifically in science education. Such accumulation of evidence, meta-analysis, and research synthesis (as it has been variously called) can be done by treating studies or statistics within studies that are tabulated across studies as units of analysis. A population or sample of studies may be drawn, and the usual simple and advanced techniques may be applied. The statistics analyzed can include the signs (positive or negative), the magnitude (such as correlations or effect sizes), or probabilities of the relations. In addition to estimating the overall effect size on, or correlation with, learning for each factor, the dependence of the relation on: sample characteristics such as size, sex, and grade level; construct or psychometric properties of the factors; and methodological features are important to estimate.

A SYNTHESIS AND CRITIQUE OF SELECTIVE RESEARCH ON ABILITY,  
DEVELOPMENTAL LEVEL, AND QUALITY AND QUANTITY  
OF INSTRUCTION INFLUENCES IN SCIENCE LEARNING

F. David Boulanger

University of Illinois at Chicago Circle  
Chicago, IL 60608

Walberg's (1978) Productivity Model identified eight constructs substantially related to school learning. The purpose of this study was to review and quantitatively synthesize the 1963 through 1978 grade 6 through 12 science education research in four of those construct areas. The four constructs are ability, age or developmental level, and quality and quantity of instruction. A quantitative synthesis over this period would provide researchers and practitioners estimates of the degree of influence of each construct on science learning, identify gaps and weaknesses in the research, and provide a basis for policy decisions on research needs in science education. These objectives are in harmony with the needs expressed by the NARST-NIE Commission on Research Priorities in Science Education (Yager, 1978).

Methodology

Beginning with the ERIC bibliographies and annual reviews of science education research as guides, published studies with grade 6 through 12 students in the 1963-1978 period were scanned to identify all correlational or experimental studies relating any of the four constructs to cognitive, affective or psychomotor science learning. Glass' (1978) techniques of meta-analysis were applied including numerical coding of approximately 40 study characteristics per study with reported correlations or effect sizes as dependent variables. Computer analysis of coded information was employed where warranted by the quantity of coded information. Relationships between the dependent variables and study characteristics were investigated. Of particular interest were the relationships of the quality of measures used, subject characteristics, and study design features and flaws with the correlations or effect sizes.

### Results and Conclusions

Thirty-four studies relating ability to learning outcomes in science were found to be highly consistent in mean correlations across ability and outcome subcategories. The study characteristic accounting for the greatest amount of non-random variability in reported ability-cognitive outcomes correlations was the reliability of the ability and outcome measure.

Fifty studies in five subconstructs of the quality of instruction construct revealed mixed results on the effectiveness of various experimental interventions. Published studies on the use of pre-instructional strategies, especially behaviorial objects; studies on training in scientific thinking; and studies on the use of more realistic or concrete adjunct materials showed the greatest positive effects on conceptual learning. Direct or deductive strategies appeared more effective in lower grades while inductive or indirect strategies were more effective in higher grades. Only three studies on quantity of instruction were found, each showing little impact on learning.

Twenty-three studies relating age or developmental level to science learning showed ability measures to be better predictors of science learning than are measures of Piagetian stage or logical operations. A slight rise in the growth of logical operations was found in the grade 7 to 9 period. Age or grade level was found to be a poor predictor of science learning.

Recommendations for future research include more replications of studies and more consistent reporting procedures.

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A SYNTHESIS AND CRITIQUE OF RESEARCH ON  
MOTIVATION, HOME AND PEER  
INFLUENCES IN SCIENCE LEARNING

Barbara K. Kremer

University of Illinois at Chicago Circle  
Chicago, IL 60680

Walberg's (1978) Productivity Model identified eight constructs substantially related to school learning. The purpose of this synthesis was three-fold:

- 1) To provide researchers and practitioners with estimates of the influence of the constructs of student motivation, home environment, and peer environment on science learning;
- 2) to identify gaps and weaknesses in the science education research; and,
- 3) where results are sufficiently conclusive to provide a basis for educational policy decisions and research needs in science education.

Methodology

Using ERIC bibliographies and annual reviews of science education research as guides, published studies with grades 6 through 12 students in the 1963-1978 period were scanned to identify all correlational or experimental studies relating any of the three constructs to cognitive, affective, or psychomotor learning in science. Studies located under construct areas were numerically coded according to approximately 40 characteristics per study reflecting methodological strengths and weaknesses; and the characterization of the sample, construct variables, and science learning outcome.



### Results and Conclusions

The results of the literature search and selection undertaken revealed only 20 studies in these three construct areas: 5 of motivation, 13 of home environment, and 5 of peer environment. Since the number of studies located in each area was limited, quantitative meta-analysis of correlations and "box scores" was carried out.

The synthesis of results from these studies indicate that student motivation and home and peer environments are important correlates of science learning that deserve greater attention from science educators than they received in the past. Results observed for these constructs in science were also found to be similar to those of meta-analyses conducted in general education. This finding suggests that social and psychological factors on learning are independent of subject area, but further research is needed. Several methodological threats to the validity of the studies surveyed were consistently noted. It is suggested that future studies in these areas implement more rigorous designs and sampling procedures.

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A SYNTHESIS AND CRITIQUE OF RESEARCH ON CLASSROOM  
ENVIRONMENT INFLUENCES IN SCIENCE LEARNING

Geneva D. Haertel

University of Illinois at Chicago Circle  
Chicago, IL 60680

This paper reports a synthesis of research on the relation of socio-psychological environment to cognitive, affective, and behavioral learning outcomes in science education as well as other subject areas. The socio-psychological environment of the classroom was identified by Walberg (1978) as one of eight constructs hypothesized to be related to academic achievement. The purpose of the study was to estimate the magnitude of this relationship, and its variability across grades, subject areas and aspects of the learning environment considered. The study shows what kinds of classroom environments are most facilitative of science learning.

A total of 734 correlations were analyzed, from a comprehensive collection of 12 studies of 10 data sets on 823 classes in 8 subject areas, encompassing 17,805 students in 4 nations. All of these data were taken from studies carried out in naturalistic classroom settings, and all were simple, part, or partial correlations between student perceptions of the socio-psychological climate and end-of-course learning. The strengths of these relationships were studied as a function of various substantive and methodological characteristics of the studies from which the correlations were taken. A range of techniques were employed, based upon the work of Glass (1978).

Methodology

A search was made of Dissertation Abstracts, Education Index, Psychological Abstracts, Social Science Citation Index, and, since much of the relevant research involved science curricula, the annual summaries of research sponsored by NARST for the years 1963 through 1978. All studies involving naturalistic classroom settings that reported simple, partial, or part correlations between student perceptions of socio-psychological climate of their classes and end-of-course learning were selected. Information on eight characteristics was recorded for each correlation taken from these studies:

National location of the study, grade level and number of students, unit of analysis, type of correlation, type of socio-psychological perception, outcome domain, and content area of subject-matter (biology, physics, etc.). In all analyses, the correlation of environment perception and learning outcome was the dependent variable. The eight characteristics were used as independent variables. Several analytical techniques were used: simple tabulations, correlation-weighted one-way analyses of variance, and weighted multiple regression analyses.

### Results and Conclusions

It was concluded that the magnitude of the correlations was dependent upon the aspect of the socio-psychological classroom environment measured, the unit of analysis for which the correlations were computed, and the nation in which the study was conducted. Learning outcomes and gains, including student achievement, performance, and self-concept, were found to be positively associated with student-perceived Cohesiveness, Satisfaction, Task Difficulty, Formality, Goal Direction, Democracy, and Material Environment. Negative associations were found with Friction, Cliques, Apathy, and Disorganization. These findings were largely in accord with theoretical predictions made by Walberg (1969). Of 36 hypotheses, 31 were supported. Correlation size did not depend upon the number of students tested, the subject matter taught, the learning outcome domain (cognitive, affective, or behavioral), or the presence versus absence of statistical adjustments for ability or pretest scores.

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THE CONVERGENT VALIDITY OF THE COGNITIVE  
PREFERENCE CONSTRUCT

Euwe van den Berg

Urije Universiteit  
Amsterdam, The Netherlands

Vincent N. Lunetta

University of Iowa  
Iowa City, IA 52242

Pinchas Tamir

Hebrew University  
Jerusalem, Israel

Rationale and Objectives

The cognitive preference construct (Heath, 1964), an application of cognitive styles to science education, has been successfully applied to the evaluation of high school science curricula. However, important questions regarding the validity and interpretation of the construct and techniques for data analysis still need to be resolved (Brown, 1975). As a part of a series of validity studies, this study was designed to investigate the convergent validity of the cognitive preference construct and to develop and test new techniques for analyzing cognitive preference data.

Methodology and Design

Two instruments were constructed to measure cognitive preferences in alternative and more natural ways than conventional instruments. These and a conventional instrument were administered to 71 elementary education majors in a midwestern university and the results were analyzed utilizing a multitrait-multimethod design (Campbell and Fiske, 1959). Furthermore two statistical indices of distinctness of cognitive preference patterns were developed, one for use with ipsative (ranking) data and one for normative (rating) data.

### Instruments and Data

The Science Cognitive Preference Inventory (SCPI) is a conventional instrument which follows the format developed by Heath (1964). Cronbach alpha reliability coefficients in college samples have been better than .75 for each of the four preference modes when a rating procedure was followed and better than .60 when ranking procedures were employed.

In the Teacher Rating Instrument teachers respond to fourteen questions from which ratings of student behaviors could be derived which by definition are indicators of cognitive preference such as: reacting critically to scientific information, being interested in applications of science, or having a tendency to learn by rote.

In the Reading Instrument students are asked to indicate most and least interesting sentences in each of the fifteen paragraphs of a science reading covering four different topics. Objective scores are derived from the cognitive preference classification of these sentences.

### Results and Conclusions

Correlations of Q (questioning) and R (recall) with R, P (principles), Q, and A (applications) scores across and within instruments fulfilled most of the conditions for convergent validity. The correlations were higher in a subsample of students with highly distinct patterns of cognitive preference scores, a finding which strongly supported the validity of the Q and R modes of cognitive preference. Correlations of P and A with R, P, Q and A scores only partially fulfilled these conditions, indicating weaknesses in the P and A preference modes.

Correlations of Q and R within and across instruments strongly supported the interpretation of Q and R as opposite poles of one dimension which could be called: "critical thinking."

The indices of distinctness of cognitive preference were useful tools in the validity study. They also provided important information regarding the nature and interpretation of cognitive preferences. The indices may be used as individual characteristics in their own right.

The study was successfully replicated in a sample of high school students.



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DEVELOPMENT OF A TEST OF THE INTEGRATED SCIENCE  
PROCESS SKILLS FOR SECONDARY SCHOOL STUDENTS

F. Gerald Dillashaw  
James R. Okey

University of Georgia  
Athens, GA 30602

Rationale and Objectives

Curriculum guides and textbooks include integrated science process skill outcomes among those important for secondary school students to acquire. Along with learning science content, these students are expected to learn to develop such skills as stating hypotheses, operationally defining variables, designing investigations, and interpreting data. But if schools emphasize these skills in instruction, they also need a means to see whether they are acquired. The purpose of this project was to develop a valid and reliable test of the integrated science process skills for students in secondary schools.

Design and Procedures

A hierarchy of integrated science process skills was developed that began with simple skills and lead to the ultimate task of planning and conducting an investigation of a hypothesis. Multiple-choice test items were developed for each skill in the hierarchy. The items were designed to be nonsubject specific, that is, test items were based on content from a variety of science fields.

The test that resulted was submitted to a panel of science educators to determine if it was valid and objective. A cross section of students from six large schools in two states were used to tryout the test and provide normative data. The test was first administered to approximately 300 students in grades 7, 9, and 11. Difficulty and discrimination indices for each item and an assessment of the test readability level were used to make revisions in items. The revised version of the test was administered to a second sample of approximately 700 students in grades 7, 9, and 11.

### Instruments and Data

The Integrated Process Skills Test consists of 36 items in a multiple-choice format with four alternative responses for each item. The reading level of the test was originally 11.2 and reduced to below 9.0 for the second version.

To assess the content validity and objectivity of the test, four expert raters were used. For a total of 144 responses (4 raters x 36 items), the experts agreed with the test developers on the assignment of test items to objectives 95% of the time and agreed with the scoring of the test 97% of the time.

The first version of the test was administered to a sample of 308 students (grades 7, 9 and 11). The mean of the first version was 18.75, standard deviation = 7.59. Reliability (Cronbach's  $\alpha$ ) of the first version was equal to .88. The mean item discrimination index was .39 and the average item difficulty index was 52%.

The second version of the test was administered to a sample of 711 students (grades 7, 9 and 11). The mean of the second version of the test is 18.99, standard deviation = 7.60. Reliability is equal to .89. The mean item discrimination index is .40 and the average item difficulty index is 53%.

In addition to the summary data given above, normative data for the three grade levels on each of the integrated process skills will be presented.

### Results and Conclusions

The agreement of the raters with the test developers on the assignment of test items to objectives and on scoring was taken as evidence that the test has content validity and is objective. The results of the analysis give evidence of acceptable reliability for the test. It was concluded that the Integrated Process Skills Test is a valid and reliable instrument for assessing the acquisition of the integrated science process skills by secondary science students.

GENERAL SESSION I

Presiding:

John W. Renner

University of Oklahoma  
Norman, OK 73019

Topic:

Issues in Science Education Research



AN INVESTIGATION OF THE RELATIVE EFFECTIVENESS  
OF INSTRUCTION IN FORMAL REASONING OF CONCRETE OPERATIONAL  
SEVENTH GRADE AND COLLEGE STUDENTS

Anton E. Lawson

Arizona State University  
Tempe, AZ 85281

Objectives and Rationale

The present study has as its primary objective the determination of the relative effectiveness of instruction designed to teach concrete operational seventh grade students (ages 11-12 years) and concrete operational college students (ages 20-24 years) how to reason formally with respect to two aspects of formal reasoning -- probabilistic reasoning and correlational reasoning. Secondary objectives include determination of the amount of variance in responsiveness to instruction accounted for by initial level of intellectual development, cognitive style, and verbal IQ.

It was hypothesized that the concrete operational college students would be more responsive to instruction than the concrete operational seventh grade students in that:

- 1) their biological maturation in terms of brain growth is complete whereas the brain growth of the seventh grade students is not complete (Epstein, 1978); and,
- 2) they have accumulated a greater store of general experience during adolescence and early adulthood that can serve as a pool of connecting or generalizing experiences to help cognitively anchor the instructed aspects of formal reasoning.

### Methodology and Design

The study employed a modified version of the standard pretest-posttest control group design. Fifty seventh grade students (mean age = 12.5 years) and 62 college students (mean age = 23.6 years) were carefully selected and matched on the basis of level of intellectual development and verbal IQ. Subjects varied with respect to degree of field independence and of course age. Both groups were then given identical instruction on two aspects of formal reasoning -- probabilistic and correlational reasoning. Instructive techniques employed were based upon previous research (Adi, Karplus, Lawson and Pulos, 1978; Fischbein, 1975; Lawson and Wollman, 1976). Posttests followed to assess the degree to which the instruction proved effective.

### Instruments and Data

Lawson's (1978) 15-item Classroom Test of Formal Reasoning was used to assess levels of intellectual development. The Group Embedded Figures Test was employed to assess degree of field dependence-independence (Witkin, Oltman, Raskin and Karp, 1971). Verbal IQ was assessed by a series of verbal analogies (Shipley, 1940). Data were analyzed with both descriptive correlational and experimental analysis of variance techniques. Posttest tasks included items requiring probabilistic and correlational reasoning contents familiar and unfamiliar to the subjects.

### Results and Conclusions

The mean score for the seventh grade subjects on the test of formal reasoning was 6.6 out of 15 possible (S.D. = 2.6). The mean score of the college subjects was 6.5 (S.D. = 3.4). Thirty-one percent of the seventh grade subjects and thirty percent of the college subjects were found to be concrete operational. Mean score on the measure of verbal IQ was 13.7 out of a possible 20 points for both samples. The seventh graders proved more field independent ( $\bar{X}$  = 12.0) than the college subjects ( $\bar{X}$  = 7.8).

Overall the college subjects performed significantly better ( $p \leq .01$ ) than the seventh grade subjects on the posttest measure ( $\bar{X}$  = 16.8 and 12.2 respectively). The concrete operational college students correctly answered nearly twice as many items as their seventh grade counterparts ( $\bar{X}$  = 14.3 and 7.5 respectively). Verbal IQ and field independence were significantly correlated with posttest task success.

### Significance

Two important educational implications can be drawn:

- 1) instruction in aspects of formal reasoning, even if it occurs after the normal developmental period (ages 12 - 15 years), can be successful and should be pursued; and,
- 2) training of concrete operational students early in the developmental period for formal operations may be premature and may be more successful if delayed.

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RELATIONSHIP BETWEEN LEVEL OF  
COGNITIVE DEVELOPMENT AND ACHIEVEMENT  
AT FOUR LEVELS OF BLOOM'S TAXONOMY FOR  
JUNIOR HIGH SCHOOL STUDENTS

J. Michael Russell

Averett College  
Danville, VA 24541

Eugene Chiappetta

University of Houston  
Houston, TX 77004

The paper reports the results of an investigation into the possible relationship between eighth grade Earth Science students' cognitive developmental level (as measured by a written test developed by W. M. Grey) and their ability to answer questions at the knowledge, comprehensive, application and analysis levels of Bloom's Taxonomy.

As part of the author's dissertation study a model of problem solving was proposed and theoretically linked to Bloom's Taxonomy. In this model the application level was said to correspond to the type of student behavior which could be classified as problem solving. Six weeks of instruction was given to 274 students who were randomly assigned to either experimental or control sections. The instruction for the experimental group consisted of activities based on the problem solving method and emphasizing student operation at the application level. The control group received instruction in the same content, but in a traditional manner.

Upon completion of the instruction, all students took a 40 item multiple choice test made up of equal numbers of questions from the four taxonomic levels. Subsequent analysis of the data showed that the experimental group outscored the control group on each of the four levels ( $p \leq .001$ ). The results of a discriminate analysis led to the conclusion that the analysis level questions contributed most to differentiating the two groups and supported the major hypothesis of the study, that activities



patterned after the problem solving model contribute to a student's ability to think at higher levels as measured by Bloom's Taxonomy.

The same students were also given the "How's Your Logic Test" devised by Grey. The proposed presentation will examine the possibility of a relationship between students' scores on each of the four taxonomic subscales of the achievement test and their Piagetian developmental level as determined by Grey's test. The implications of the presence or absence of such a correlation will be discussed with reference to classroom teacher behavior and types of activities appropriate for middle and junior high school students.



CONCURRENT SESSION C and D

Session C-2 and D-2 Techniques and Procedures of Research

Topic: Single Subject Designs for Science Education  
Research -- The Unsung Paradigm

Donald C. Orlich  
Macarena Figueroa

Washington State University  
Pullman, WA 99164

The theme of the 1979 NARST Convention was the "Impact of Learning Paradigms in Teaching Research." Carl F. Berger's conference address "What are the Implications of Paradigm-Based Research for Science Education Research" tended to support traditional research designs. The major presentations at a general session stressed:

- 1) Reception Learning (Novak);
- 2) Hierarchical Learning (Jones); and,
- 3) Developmental Learning (Lawson).

The nation's leading science education researchers had no formal presentation about single subject paradigms at the conference.

No paper's using single subject design have been given at the last four NARST conventions. An intensive review of JARST issues from 1967 to present failed to reveal one published paper using single subject design (SSD). It may be inferred that NARST members are either unfamiliar with SSD or are not using SSD in their research efforts.

The objectives of this presentation are to:

- 1) describe the basic rationale and procedures of SSD;
- 2) analyze selected SSD models for their appropriateness to science education; and,
- 3) describe the applicability of SSD to NARST members.

The use of SSD as an evaluation tool will also be presented. As SSD may be used with as few subjects as one and as many as an entire group or classroom of students, the concept of replication will be noted.

With the current stress on accountability and the concomitant scarcity of science education research funds, members of NARST must learn new and powerful research designs. Finally, with the advent of PL 94-142, The Education for All Handicapped law, more science educators will focus on research with handicapped children. This specific group is too small to use the traditional research paradigms, thus SSD will be required.

Finally, we will suggest studies previously published in JARST that could have utilized SSD.

STATUS AND NEEDS OF SCIENCE EDUCATION:

A REPORT ON PROJECT SYNTHESIS

Wayne W. Welch

University of Minnesota  
Minneapolis, MN 55455

Ronald D. Anderson

University of Colorado  
Boulder, CO 80302

Harold Pratt

Jefferson County Schools  
Lakewood, CO 80215

In 1976, the National Science Foundation sponsored three large-scale studies of the status of science education. Contracts were awarded for a literature review (Helgeson, Blosser, and Howe, 1977); a series of case studies (Stake and Easley, 1978); and a national survey of current practices (Weiss, 1978). The information generated by these studies was extensive and required further synthesis.

In 1978, the Foundation funded a research proposal designed to provide interpretive consolidations of these three studies as well as the three national assessments that had been carried out in science. Project Synthesis is a data reduction and interpretation project whose purpose is to give meaning to the vast quantity of information recently available in science education. In this paper, we describe the data synthesis process and report the major findings of the study. Implications for educational policy are also discussed.

The research plan used by the Project Synthesis group was a three-stage discrepancy strategy. The actual state of affairs as described in the four primary data sources was compared to a pre-determined desired state in order to identify discrepancies. Groups of consultants, representing five different perspectives (biological science,

physical science, inquiry, elementary science, science/society/technology) defined what they considered to be a desirable status for the discipline. The information sources were then perused to determine the actual status. Discrepancies between the desired and actual state were identified and represent the major findings of the study. These include:

1. The desired state of affairs for elementary science, as defined by the group of educators, is not accepted nor valued by parents, administrators, and most teachers.
2. Present societal and school conditions serve to act as barriers rather than facilitators to the implementation of the desired science program.
3. Elementary teachers are not prepared nor interested in teaching science.
4. The biology presently taught in the schools, and based on the structure of the discipline, differs in philosophy, historical perspective, goals and content from the human-oriented biology advocated by the biology focus group.
5. The contribution the physical sciences can make to personal needs, societal issues, and career preparation is largely ignored at the expense of emphasizing fundamental knowledge of the discipline.
6. Science, especially physical science, is not a valued part of the public school curriculum of general education for all students.
7. The desired classroom practice, contextual support, and student outcomes that would indicate student understanding and application of the processes of scientific inquiry are far from being met.
8. The educational system has systematically excluded, not only the study of technology, but the study of science and technology as it relates to and interacts with the changing society.

The conclusions reached by the Project Synthesis group do not present a very encouraging picture for science education. The image is further darkened by the fact that we have just come through an extensive 20-year period of federal support. However, the defined discrepancies do suggest several recommendations for the future and are presented in the paper. The underlying theme for the recommendations is "responsiveness." We believe those charged with the teaching and

learning of science must actively respond to the environmental forces that determine what science education will be taught in the schools. Chief among these are the social environment of the schools, including parent and teacher values, student characteristics, our current knowledge of pedagogy, and the nature of science. We must be sensitive to all of these factors if we ever hope to provide the kind of science program needed by our children.

We are at the dawn of a new era in science education. We seem to have failed in our efforts to shape education by relying on the specialists in the subject matter disciplines. It is time we turn, instead, to those people intimately involved in education for new direction and guidance. Let us hope that the joint efforts of teachers, school managers, parents, and science educators are successful in meeting the changing and complex needs of individuals and of society.

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CONCURRENT SESSION C AND D

Session C-4 and D-4    Techniques and Procedures of Research

Topic:                    Applying and Interpreting Multiple Linear  
                             Regression Analysis Procedures

Arthur L. White

The Ohio State University  
Columbus, OH 43210

Carl F. Berger

University of Michigan  
Ann Arbor, MI 48109

This session has been designed to provide a general conceptual base for multiple linear regression so that participants can better apply and interpret the results of the application of these procedures. The session will be conducted with application as the major focus. The knowledge of multiple regression analysis necessary to set up the control cards and interpret the results for the BMD and SPSS computer programs will be the conceptual content of the sessions. Examples will be distributed and discussed throughout the session. It will be assumed that the participants have basic knowledge of correlation and simple analysis of variance. All participants should bring a calculator which has the four basic functions and a square root key.

AN ANALYSIS AND COMPARISON OF ELEMENTARY  
PRE-SERVICE AND IN-SERVICE SCIENCE TEACHERS'  
BELIEFS ABOUT TEACHER CLASSROOM BEHAVIORS

Willis J. Horak

University of Arizona  
Tucson, AZ 85721

Teacher attitudes and beliefs have been studied by educational researchers for many years. Early research studies by Kerlinger (1956), Ryans and Wandt (1952), and Gibb (1955) have suggested that there are common groups or dimensions of behaviors and beliefs about educational practice. Wehling and Charters (1969) later identified eight dimensions of teacher beliefs that were not unique to particular populations, and Sontag (1968) analyzed the dimensions of teacher perceptions of classroom behavior and identified four recognizable factors in various teacher samples. In the area of science education, recent studies have been reported by Bybee (1975, 1978) and by Horak and Lunetta (1979). These studies have generally shown that groups of science teaching behaviors may be prioritized and that types of science teachers may be identified relative to their beliefs about the importance of specific science teacher behaviors in the classroom.

The main objective of this study was to see if specific science teacher types could be identified among elementary inservice and preservice teachers. Additionally these science teacher types for each sample were analyzed for their correlation with previously reported teacher types identified in junior and senior high school science teachers.

Q-methodology and techniques were used to analyze the belief patterns of teachers with respect to statements dealing with the classroom behaviors of science teachers. The instrument used was the Science Classroom Behavior Q-sort (Horak and Lunetta, 1979). This instrument has reported content validity and test-retest reliability of 0.810. The sample for this study consisted of 80 preservice elementary teachers and 80 inservice elementary teachers from a regional area. In Q-methodology, selection of the participants is not usually done randomly, but rather they are chosen to represent identifiable divisions of the population

with which the study is concerned. For this study, background characteristics and grade preferences of the participants were used to help identify relevant segments of the teacher population.

The data consisted of the 160 participant's sorts of the 80 behavioral items into a quasi-normal distribution. Beliefs about the relative importance of specific science teaching behavior were determined by item rankings on an 11 point scale ranging from perceived most important behaviors to perceived least important behaviors. The data obtained was analyzed using an extended factoring program which provides a single-execution method for handling all phases of Stephenson's Q-analysis.

Similar science teacher types were identified in both the pre-service and the inservice samples. These science teacher types were additionally found to correspond closely with types previously identified and reported for junior and senior high school science teachers. The percentages of teachers identified with each type were, however, different. Descriptions of the science teacher types also showed that they could generally be associated with underlying psychological theories. These results extended the generalizability of the previously reported research to include elementary preservice and inservice science teachers. They also indicated that it may be necessary for future research on teacher beliefs and behaviors to consider teacher actions in a more global sense, as well as for science teacher education institutions to include modules in their curriculum that relate to relevant behaviors for these broad categorizations of science teachers.

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USING SCIENCE ACHIEVEMENT TO  
VALIDATE STUDENT TEACHER COMPETENCIES

William Capie  
Kenneth G. Tobin  
Margaret Howell  
University of Georgia  
Athens, GA 30602

Objectives

This study was designed to determine the validity of competencies which are the basis of professional teacher certification.

Rationale

Georgia is implementing performance assessment as part of the teacher certification process. The Teacher Performance Assessment Instruments (TPAI) (Capie et al, 1979) have evolved over a three year period to assess essential competencies. Competency selection and instrument development were described earlier (Okey and Capie, 1979). A preliminary edition was used in this study. Each competency is defined by two to five specific behavior statements called indicators. Each is rated on a five-point scale representing degrees of increasing proficiency. The five scale points are defined to reduce ambiguity and enhance interrater agreement.

The instruments have been studied extensively to determine their technical characteristics. Modifications have been made based on formal and informal feedback, studies of interrater agreement and internal consistency, factor analyses, and various validity investigations. The best measure of validity has been considered the ability to predict student achievement. Consequently, this study was planned to determine what portion of the variation in pupil achievement could be attributed to measures of student teachers' competence.

Methods

Thirty-three undergraduate interns in early elementary education and several hundred elementary pupils participated in the study.



Interns visited classrooms for two days early in the first quarter of a two quarter senior internship. They returned to campus and prepared a short science unit for use in the school. During the first full week of school activity the unit was implemented. Interns were rated on the TPAI by their science instructor as well as an instructor in general methods after independent observations.

Thirty-six TPAI indicators comprising twelve competencies were rated. In addition, factor scores based on analyses by Tobin et al (1979) were computed. All scores were available from both data sources as well as from the combination of the two.

Pupils were pre- and posttested on unit objectives with instruments developed by the interns. An effectiveness index derived from the pre-and posttests was the class mean of a measure called the percentage of the remaining gain computed for each pupil. The difference between the post- and pretest (observed gain) was divided by the difference between the maximum possible score and the pretest score (possible gain) and then multiplied by 100 to compute the percentage of remaining gain (split-half reliability = 0.92).

A multiple regression of the factor scores against the teacher effectiveness index was completed. Pearson product moment correlations were computed between the effectiveness index and each indicator rating and each competency and factor score.

### Results

A total of 71 significant correlations were identified ( $p \leq 0.05$ ) in the various analyses. A summary is reported in Table 1. Correlations ranged to 0.72 for indicators and 0.66 for competencies.  $R^2$  values ranged to 0.55.

### Conclusions

The results affirm the validity of TPAI competencies among pre-service teachers. The most consistent pattern of significant correlations reflected classroom management skills. The factor scores which represent all indicators produced significant  $R^2$  values which is strong evidence for the validity of the competency set. Instrument validity is better studied with multiple raters to increase generalizability.

TABLE 1

Correlations between teacher ratings  
and pupil achievement gains in science

| First Occasion                        | Science<br>Instructor | College<br>Supervisor | Combined<br>Ratings |
|---------------------------------------|-----------------------|-----------------------|---------------------|
| Number of indicators rated            | 31                    | 32                    | 33                  |
| Number of significant<br>correlations | 17                    | 13                    | 19                  |
| Number of competencies rated          | 11                    | 11                    | 11                  |
| Number of significant<br>correlations | 9                     | 4                     | 9                   |

The complete paper discusses several related methodological issues such as multiple raters and appropriate inference level for observational instruments.

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## COGNITIVE STRUCTURES AND ACHIEVEMENT IN PHYSICS

George Pallrand  
David VanHarlingen

Rutgers University  
New Brunswick, NJ 08903

The difficulties experienced by students in introductory college physics courses are well known. The problems students encounter in such courses may account in part for the recent interest among physics teachers in the character of the cognitive structures which students possess. The thought processes called upon in understanding physics may be new to, as well as under-developed in, many students entering college. The difficulties experienced by many in the more abstract sciences and mathematics courses suggests that this relationship should be examined.

The thought processes identified by Piaget in characterizing formal thought provide a useful paradigm to examine such a question. This research examined the availability among students of a one to one matching strategy in contrast to a group strategy as these related to achievement in physics. Fifty subjects enrolled in a physics course at the university level participated in the experiment. The one to one matching strategy consisted of matching attributes of a variable to an individual instance. The group structure on the other hand enabled the subject to consider a population within which he may be included or excluded on the basis of attributes. Availability of these cognitive structures was determined from individual responses to a propositional logic test. These strategies were further related to the availability of confirming and disconfirming strategies as exhibited in hypothesis testing situations. A modification of the Wesson and Johnson-Laird four card task was used for this purpose. It was hypothesized that a confirming strategy would be used by individuals using a one to one matching strategy while those processing the group structure would use the disconfirming strategy.

The analysis indicates that ability as measured by the logic test is related to achievement in physics. The correlations between logic score and the sum of mid and final term grades was .43. The correlations between the items (conjunction and disjunction) used as a measure of the availability of a matching strategy was .39, while the correlation between the items (implication and biconditional) used as a measure of the availability of a group structure was .52. The scores on hypothesis checking items provided a correlation of .54 with group structure items and .15 with matching strategy items.

The correlations between logic items and the hypothesis checking task exceeded those with physics achievement. This suggests that students demonstrating the more limited cognitive structures may attain at best an average grade while those possessing the more advanced structures may be distributed over the entire range of grades, with the greatest concentration in the above category. The existence of certain cognitive structures appears to be a necessary condition of achievement in physics. Availability of more advanced structures does not provide a sufficient condition for above average achievement. This analysis further suggests that introductory courses may not fully utilize available cognitive structures of many students.

THE RELATIONSHIP BETWEEN LOGICAL OPERATORS AND  
ACHIEVEMENT IN UNIVERSITY PHYSICS

Walter Lockwood  
George Pallrand  
David VanHarlingen

Rutgers University  
New Brunswick, NJ 08903

Recent studies have shown significant relationships between physics achievement and performance on tasks involving the analysis of statements relating to logic structures. These statements have emphasized logical operators such as conjunctions, disjunctions, implications and biconditional situations. It appears that conjunctions and the inclusive disjunction are poorer predictors since nearly all students tested possess the structures associated with these tasks. The combined scores of the implication and biconditional statements are highly predictive as are the total combined scores.

This investigation deals with the observation that a very small subset of answers or choices are very nearly equivalent in predictive power to the total test score. This subset, called the "null" set are the included but non-specified items on the implication and biconditional statements. It appears that the null set, consisting of 12 items, was as nearly predictive of success as the 64 item total score.

The sample for this study is comprised of students from similar populations of first year university physics students. The first group 224 was selected from 500 science majors enrolled in the 1978-79 school year, a second group of 50 from 105 students in the 1979 summer session, and the third group consisted of 440 of 775 students in the 1979-80 school year majoring in engineering.

There is a distinctly bimodal distribution of the scores which is highly consistent. Over the three sequential test periods the distributions for the group of nearly 1600 students are very similar. Approximately 15% of the students taking the test miss all 12 items and over 30% answer them all correctly.



Nearly 50% of all the errors on the test were observed to occur in this subset of answers. A significant relationship appears to exist between the total number of these items missed and final grade, early course withdrawal and the number of class dropouts.

Comparison of the lower end of the "null" set distribution scores with lower grades, D and F, and dropouts show a Pearson product moment correlation coefficient of .3 which is statistically significant at the .001 level. These results indicate students scoring low on this 12 item subset test have a very high probability of performing poorly in a university level physics course.

Detailed analysis of student behavior when solving extended logic type problems indicated those missing many items on the null set tended to use a one-to-one matching strategy while those missing none or only a few tended to view the larger set of items as groups or in a holistic manner. There did appear to be a transitional state in which the subject used a varying mix of the two strategies.

Very poor performance on the "null" set appears to indicate that these students generally will earn grades of C or lower. Clinical interviews are needed to determine whether the use of a matching strategy is related to a student's strategy for solving physics problems.

COGNITIVE STRUCTURE UTILIZATION IN COMMUNITY COLLEGE  
AND UNIVERSITY SCIENCE COURSES

Walter H. Rothaug  
George Pallrand

Rutgers University  
New Brunswick, NJ 08903

Frequently students who successfully complete a developmental (remedial) science course encounter difficulties when they subsequently enroll in a college level science course. Recent research suggests such difficulties may be related to the unavailability of certain cognitive schemes. Our research examines the relationship between availability of a one-to-one matching strategy in contrast to a group strategy and achievement in science courses. This research, conducted among forty-four community college developmental chemistry students and fifty university physics students, provides some explanation for the aforementioned difficulties.

The instruments used were a logic test and a hypothesis checking task. The correlation among the community college students between logic test score and developmental chemistry final course grade was .59, comparing with a correlation of .51 between the same logic test and final grade in the university physics course. The logic test was then split into two parts. The correlation with final grade between items (conjunction and disjunction) of the logic test used to measure the availability of a one-to-one matching strategy was .53 with a median score of 28 out of 32 for the community college students. This contrasts with a correlation of .39 and a median of 31 for the university students. The correlation with final grade between items (implication and biconditional) of the logic test used to measure the availability of the group strategy was .46 with a median of 19 out of 32 for the community college students. In contrast the correlation was .45 with a median of 29 for the university students. The significantly lower median score for the community college students indicates that the group strategy is not as fully developed among them as among the university students. This contrasts with the individual matching strategy where the medians of the two groups are almost equal and not significantly different.

The score on a hypothesis checking task provided correlations of .46 with group structure items and -.10 with individual matching items with a median of 1.8 out of 8 for the community college students. This contrasts with correlations of .52 and .15 with a median of 3.6 for the university students.

These results may provide some insight into the difficulties encountered by students when they complete a developmental science course and enroll in a full college level course. A large component of achievement in a developmental science course is mastery of the terminology and vocabulary of the science, a necessary skill, but one with a large verbal component. In contrast, in the college level science courses, the logical component tends to predominate in achievement. Students who do not possess more fully developed cognitive structures (those who can utilize one-to-one matching strategy but not the group structure) are able to successfully complete the developmental course but encounter difficulties with the college level courses in science. Those who possess the more fully developed structures usually encounter no difficulties with the developmental course and are able to function in the college level science course as well as any other students.

## COGNITIVE FACTORS AND PHYSICS ACHIEVEMENT

David VanHarlingen  
George Pallrand

Rutgers University  
New Brunswick, NJ 08903

Introductory physics courses at the college level have frequently produced difficulties for many students who had not encountered such frustrations with other academic subjects. A number of studies have attempted to determine whether certain abilities distinguish successful students (those attaining an "A" or "B") from unsuccessful students (those attaining "D" or failing grades). Many of these studies have focussed on SAT scores, basic mathematical skills, Piagetian items, prior exposure to science or mathematics, grade point averages and other broad background variables.

This study focused on determining whether physics achievement could be related to sets of cognitive factors covering mathematical ability, logical reasoning, two spatial dimensions, and verbal ability. The subjects were 519 students, mostly sophomores completing the first semester of an introductory calculus-based physics course aimed primarily at students majoring in the sciences at an eastern state university. Of these, approximately 85% also completed a pretest consisting of a three part mathematics test, three tests of logical reasoning and three spatial tests. SAT scores were also obtainable for about 75% of the subjects.

Principal components factor analyses were performed using first only the independent variables and then including the dependent variable (physics achievement): The total score on three physics tests taken during the semester.

The first factor analysis produced two factors: One comprised of the mathematical tests and logical reasoning tests; the second was comprised of the spatial tests. When physics tests were included, they loaded on the same factor as the math and logic tests. The two factors accounted for nearly 60% of the variance in the first instance and only slightly less than that in the second.

A regression analysis was completed using the individual tests to determine the contribution of more specific abilities to physics achievement.

Thirty percent of the variance in physics score was attributable to three tests: The overall math ability, a test of propositional logic and a test of visualization. When the tests were broken into subparts, the parts of the math test most predictive were those involving items from calculus and functional relationships, and those from geometry and trigonometry. Items on the logic test involving implications and biconditional statements were also significant predictors.

It appears from these results that a logical-mathematical ability is of major importance in succeeding in physics. Our secondary schools and early college courses need to concern themselves with solidifying students mathematical foundations, especially in second and third year courses and developing logical reasoning ability involving conditional statements for students intending to major in the sciences.



## SCIENCE EDUCATION AND BILINGUALISM

Mary Ellen Quinn

Edgewood Independent School District  
San Antonio, TX 78230

Carolyn Kessler

University of Texas at San Antonio  
San Antonio, TX 78230

The purpose of this paper is to present statistical evidence that bilingualism has a positive effect on the ability of students to formulate scientific hypotheses or solutions to science problems and then to offer a possible explanation for that positive effect together with its implications for science education. An explanation of the results is based on Piagetian theory. Implications of the study apply to language as well as science education.

The subjects who formed the sample of this investigation were sixth grade students in six intact classrooms. One treatment and one control group were monolingual English-speaking children from an upper socio-economic area in suburban Philadelphia, Pennsylvania. Another treatment and control group came from a low socio-economic area in South Philadelphia. Of this group, one section was monolingual English-speaking, another section was Italian-English bilingual. The third group consisted of Spanish-English bilinguals in a very low socio-economic area of San Antonio, Texas. All of the last group had participated in bilingual education programs during primary grades, an opportunity which had not been available to the Philadelphia bilingual children.

All subjects in the treatment groups participated in a series of twelve science inquiry film sessions and six discussion sessions, each 40 minutes in length. Each film session, based on a three-minute film loop depicting a single physical science problem, ended with the students writing as many hypotheses as they could in a rigorously controlled twelve minute period. The individual papers were then scored using the Hypothesis Quality Scale developed by Quinn (1975). At the end of the 18-lesson instructional

period, a new series of hypotheses was elicited and scores from these were used as the criterion variable. Analysis of covariance was then used to compare the following: Treatment with control groups, socio-economic groups and monolingual with bilingual groups of children.

A modification of Campbell and Stanley's Design Twelve (1963) was employed with analysis of covariance. Before being given any instruction in hypothesis formation, students in the three control groups were tested on the criterion variable. In effect, this meant that each control group constituted a non-treatment group, a technique permitted by Campbell and Stanley's Design Twelve when its assumptions are met. Those assumptions were met in this study. Instruction in hypothesis formation preceded the criterion variable test for the treatment groups. The Hypothesis Quality Scale proved to possess an interjudge reliability coefficient of 0.94 when tested by the Nash-Beyers interjudge reliability computer program based on Winer (1962).

Results indicate that the treatment groups performed significantly better than the control groups. There was no significant difference between the socio-economic groups. The bilingual children performed significantly better than the monolingual children at both high and low socio-economic levels.

Piaget's theory of internal conceptual development offers explanatory power for the observed differences between the monolingual children and the bilingual children of this study since the bilinguals apparently experience more fully the conceptual conflict that triggers accommodations in cognitive development, a position that would account for the superior scores of the bilingual children.

The results reported here have implications for science education as well as language education. They suggest, among other things, that students educated in more than one language will be better science problem-solvers than their monolingual peers. For science educators at all levels this could mean the active seeking of bilingual students. This could in turn mean a closer working relationship between language and science educators.

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PREDICTORS OF OVERALL ACADEMIC, SCIENCE, AND  
MATHEMATICS ACHIEVEMENT IN BLACK,  
INNERCITY ADOLESCENTS

Mae T. Lee

Community School District #4  
New York, NY 10035

Theresa J. Jordan

New York University  
New York, NY 10035

Tina J. Jacobowitz

Montclair State College  
Upper Montclair, NJ

The purpose of this investigation was to examine the relations among the predictor variables, verbal ability, academic self-concept, and academic locus of control and the criterion variable, achievement, i.e., overall academic, science, and mathematics achievement. Previous studies (Jordan, 1979; Jordan and Jacobowitz, 1979) conducted at Project City Science with black, innercity adolescents showed that academic self-concept was more predictive of academic achievement in boys than in girls. A similar trend occurred in science and mathematics achievement. Furthermore, there were no significant cross-sex differences in academic self-concept. That is, although both boys and girls held similar perceptions of their academic capabilities, the relation between these self-perceptions and achievement variables was significantly stronger for boys than for girls. What accounts for this discrepancy? From ongoing classroom observations, we noted that teachers demonstrated differential reinforcement patterns. Girls were generally reinforced for more stereotypic verbal behavior, while boys were reinforced for more reality-based, situation-specific behaviors. For example, in science classes boys were reinforced for "hands-on" as well as verbal skills, while girls were only rewarded for verbal performance. Though girls perceived that they could perform academically, they may not have felt they possessed control over actual achievement.

Hence, the critical affective variable in addition to academic self-concept is academic locus of control. Consequently, a measure of this variable was included as a predictor to explain this sex difference.

Three instruments were administered on a group basis to 229 (108 males and 121 females) black eighth grade innercity students: The Self-concept of Academic Ability Scale, the Intellectual Achievement Responsibility Scale, and the Peabody Picture Vocabulary Test. Overall grade point average, science, and mathematics grades were the criterion measures. To minimize reading problems, all instructions and items were read aloud.

Both commonality and multiple regression procedures were employed in the data analyses. These data were analyzed separately by sex.

Some salient findings were:

1. Verbal ability in combination with academic self-concept and locus of control contributed significant proportions of variance to overall academic as well as science and mathematics achievement for both sexes.
2. For boys, all three independent variables contributed significant proportions of unique variance to overall academic achievement. For girls, only verbal ability and academic self-concept contributed significant proportions.
3. Academic locus of control was not a significant predictor of science achievement for either sex. However, it was a significant predictor of mathematics achievement in boys.

Our hypothesis that academic locus of control would explain the sex discrepancy in relations between the affective and achievement variables was not substantiated. Results indicated that for females, locus of control was not a significant predictor of achievement. However, for males, it was a potent predictor for overall as well as mathematics achievement. These intermediate results suggest a need for differential reinforcement for the two sexes. While enhancement of academic locus of control may lead to higher achievement for males, it has no effect on females. In future analyses of these data we need to control for the effects of verbal ability and to examine further sex differences.

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THE ANALYSIS OF A TAILOR-MADE CURRICULUM  
AND ITS IMPACT UPON 5TH AND 6TH GRADE MINORITIES  
AND FEMALE CHILDREN

Westbrook A. Walker

Arizona State University  
Tempe, AZ 85281

Rationale and Objectives

Science is taught in elementary schools to bring about pupil growth in the cognitive, affective and psychomotor domains of knowledge. Beisenhertz (1972) stated that in most classrooms a major part of the school day is spent with language arts and mathematics being taught as mechanical states with little or no deviation in approach from day to day. Now science is slowly being integrated into that mode causing children to lose interest in the process of sciencing. Walker (1973) found that:

1. the use of a variety of strategies employed in science teaching offered the participants the procedural option of selecting and utilizing a specific strategy for his/her own learning style;
2. the application of a "tailor-made" instructional sequence improved the abilities of minority and culturally different learners when direct, specific verbal instructions were stated in the language of their environment; and,
3. the use of action verbs to articulate a specific objective proved effective in increasing the participant's ability to achieve.

The purposes of this study were:

1. to develop an embryonic structure for an experimental instructional technique in science so that the design and philosophy encourage the use of varied teaching techniques in meeting the need of a participating learner;
2. to measure any positive increase in performance or any fluctuation in performance resulting from the use of the technique; and,
3. to develop and evaluate an instrument by use of a particular technique for isolating other variables.

#### Methodology and Design

Sixty-seven elementary children from one school were used in a large group setting from an inner city area. The sample consisted of 21 fifth grade and 46 sixth grade youngsters, all divided into three classes. This sample included six Mexican-Americans, one white American, and sixty black Americans. All volunteered to participate in the study. The behavioral skills to be developed in the study were distinguishing and manipulating. The processes used to engender these behaviors were:

- (a) team teaching
- (b) individualized instruction
- (c) programmed instruction
- (d) laboratory-oriented instruction

The media selection included instructional television, video-tape recording, electromagnetic tape-recordings and 16-millimeter films.

The design used for this study was a one group pretest-posttest time series design which utilized multiple measurement processes on the experimental group and introduced continual treatments during the time series of measurement. Stanley and Campbell (1963) diagrams this in the following fashion:

O<sub>1</sub> O<sub>2</sub> O<sub>3</sub> O<sub>4</sub> X O<sub>5</sub> O<sub>6</sub> O<sub>7</sub> O<sub>8</sub>

#### Instruments and Data

The evaluation instruments were composed of fifteen 8 x 10" high-glossed magnetic photograms produced by a photographic chemical process.

The lines of force captured on the magnetic photograms were produced by manipulating magnets beneath photographic paper sandwiched between two clear sheets of plexiglass. Iron fillings were sprinkled on the plexiglass producing the lines of forces to be reproduced by the learner. Written questions were developed for the study to accompany a pictorial diagram of randomly arranged particles. Drawings of symmetrically arranged particles were also designed to explain magnetized and non-magnetized substances.

The statistical tests used on data collected were the analysis of variance, analysis of a multivariate linear model, and the univariate and multivariate analysis of variance, covariance and regression for trend analysis.

### Results and Conclusions

The tests of the null hypotheses stated for the study resulted in the rejection of certain hypotheses. On measurements  $O_1 \dots O_8$  tests of gains were made and were significant at the .01 level. Repeated measures, between groups and by groups were all significant at  $p \leq .0001$ . There was mean achievement in observation which showed significance at the .01 level. Language usage proved significant at the .01 level. The posttest showed no significant difference for all groups. Correlations showed that the participants were able to solve problems without being excellent readers. Correlations between language usage and concept developing skills were positive and significant at the .05 level.

Moreover, the study concluded that the difference in use of the strategies provided in this study offered the participants of the study procedural options of selecting and utilizing the strategies which were suitable for their learning styles; the use of nonverbal instruments allowed for cultural freedom, and achievement was significant.

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## ANALOGIC MODELS IN THE LABORATORY EXERCISE:

### ONE METHOD FOR TEACHING TO THINK

Gerald T. Johansen, Sr.

Cornell University  
Ithaca, NY 14853

Recent writings in educational and science philosophy and in educational psychology have begun to focus upon the very activities that represent how thinking begins, and how this thinking manifests itself in the creation of the various disciplines of man's intellectual endeavors. The products of this thinking within the various disciplines are the sorting systems which become the conceptual and methodological means by which questions are posed and answered within that discipline. The works of Elkana, Kuhn, Toulmin, and others in science philosophy stress that the purposeful activity of conceptual construction is uniquely dependent upon the cognitive "goggles" of the knowledge creator. Ausubel and Novak have articulated a cognitive theory of learning which demonstrates how concepts are learned and how these concepts become the subsumers so that new concepts can be learned meaningfully. Belth, in an attempt to articulate the models of a discipline of education, has defined the act of thinking as metaphorizing or analogizing. The teaching models, deducible from Belth's theory of the discipline, become the sorting systems by which the teacher and student can "see" the structure of a piece of knowledge, how that knowledge is created, and how that knowledge can later be changed or transformed to form new types of knowledge.

This paper attempts to show how these various avenues of concern from philosophy and psychology can be merged together to form a coherent theory of teaching and learning. As an example of this, the laboratory exercise is shown to be a paradigm case of the theory, and a means by which students can be taught to think. The laboratory exercise, thought previously to demonstrate only the "process" of science, can now be used to demonstrate a facet of the conceptual nature of science and to teach students that the construction of an experimental design represents a particular kind of analogy, one that is based upon the ideas that what happens in the laboratory is an analogue of what occurs in nature. Anecdotal evidence from actual classroom experiences with this teaching strategy will be discussed.

EFFECTS OF DIAGNOSTIC TESTING ON ACHIEVEMENT, RETENTION,  
AND ATTITUDES OF HIGH SCHOOL BIOLOGY STUDENTS

Sandra Hall Holmes  
William Capie

University of Georgia  
Athens, GA 30602

Objectives

The purpose of this study was to determine if achievement of high school biology students and attitudes toward the topic were affected by using diagnostic tests.

Rationale

The goals of mastery learning would be endorsed by most teachers but implementing a mastery learning program is difficult. Implied in the mastery learning model is pre-testing, instruction based on test results, posttesting, with reteaching and retesting continuing until an acceptable mastery level has been obtained. The logistics of such a system are beyond the capability of most teachers.

Writers (Brandt, 1976; Okey, Brown, Fiel, 1972) have advocated beginning to implement the mastery learning model in a manageable way. Suggestions include beginning with one or two units or allowing students to manage scoring chores.

Another approach is to determine which elements of the mastery learning program are critical to its effectiveness. Diagnostic testing has been postulated as the key element of the program (Okey, 1974; Airasian, 1971). Diagnostic testing has been shown to increase achievement in science instruction in several studies at the middle school and college level (Saunders, 1978; Yeany, Döst and Matthews, 1979). Consequently, this study was undertaken to determine if diagnostic testing would affect achievement among high school students.



### Methods

The subjects in the study were 37 tenth grade students in two Survey of Biology classes. Because students were assigned by computer to classes, no systematic difference existed between them. One class was randomly chosen as the treatment group.

The treatment spanned three two-week units. The same methods were used in each class except that one received only objectives for the unit while the other also took diagnostic tests over one to three days instruction. Five to ten minutes were required for each test including scoring by the students; results were not known to the teacher.

Students took a summative test over each unit and a comprehensive test two weeks after the experiment. The teacher-made objective tests were validated against unit objectives. Reliabilities for the four tests were .87, .85, .85 and .81, respectively.

Attitudes were assessed with a questionnaire consisting of statements which the students rated on a five-point scale from strongly disagree. Scores represented the sum of the values for all items with positive values being rated 5. Alpha reliability for this measure was .65.

An analysis of variance was completed on each set of data.

### Results

Group means for the first two tests were nearly identical. On the third summative test and on the retention test there were significant differences in achievement favoring the treatment group.

There also were slight but significant differences in attitude favoring the treatment group.

### Conclusions

This study did show that diagnostic testing increased achievement among biology students. As in studies with students at other levels, the effects were not immediately apparent. Some time may be necessary for students to become convinced that testing really helps.

Attitude differences were small but desirable. It does seem reasonable that students who do well will have positive attitudes, even though this effect has not been demonstrated consistently.

It is encouraging that a relatively simple procedure such as using the short diagnostic tests several times each week can increase achievement. However, no study has shown that the effects would persist if the treatment were maintained for a longer period.

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AN ANALYSIS OF METRIC ACHIEVEMENT  
USING TWO MODES OF COMPUTER INSTRUCTION

A. W. Strickland  
Pete Sturm

Indiana University  
Bloomington, IN 47405

The potential for effective instruction via the computer medium has been substantially demonstrated (Linaburg, Marshall, Gaston, and Snodgrass, 1974; Strickland, 1979a; Strickland, 1979b; Okey and Majer, 1976; Duell and Smith, 1973). Since the use of computers in some form seems judicious, the quest for refinements might then be the next plateau.

The goal of this research was to examine the effectiveness of two instructional modes using the PLATO IV computer system in delivering metric instruction to upper division college students. The two modes selected were:

- 1) a linear interactive instructional mode  
(e.g., drill and practice); and,
- 2) a branching interactive mode  
(e.g. tutorial).

Ninety subjects were randomly assigned to one of three treatment groups -- the two computer instructional modes, and a placebo group. Subjects were administered an attitudinal measure (related to computers), a metric pretest, and a short-term memory test prior to instruction. All groups received a posttest measure evaluating metric achievement.

Comparison of performances on posttest scores indicated a significant difference between the placebo and the experimental groups, moreover the branching interactive mode proved to be significantly more effective in altering the subjects' metric achievement. In addition, the subjects experiencing the branching interactive mode displayed a more positive change in attitude toward computers.

This research indicates that continued exploration and refinements of computer curriculum materials are needed. Additionally, the results indicated the presence of interactions between selected learner aptitudes and the instructional treatments. The plausibility of these results point the way for further exploration.

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## GENERAL SESSION II

Presiding: James Okey  
University of Georgia  
Athens, GA 30602

Topic: Crises in Science Education

### Speakers:

Robert E. Yager  
University of Iowa  
Iowa City, IA 52242

Rodger Bybee  
Carleton College  
Northfield, MN 55057

John W. Renner  
University of Oklahoma  
Norman, OK 73069

James J. Gallagher  
Michigan State University  
Lansing, MI 48824

Science education needs constant reappraisal to determine its alignment with the requirements of the people it serves. The profession must respond to new demands as it has periodically in the past.

The problems of society are vastly different today and the conditions affecting them are changing more rapidly in the current age than they ever have in the past. The public is confronted with many science related social issues and their understanding of these issues will determine the ability of our society to respond effectively. The science of the 1970's and 80's is different than it was previously. Hence with social conditions (society) and science in a period of significant change, science education must respond; it cannot be static. Clearly, some new directions for science education are needed.



THE RELATIONSHIP BETWEEN STUDENTS' ATTITUDE AND  
ACHIEVEMENT IN CHEMISTRY AND CLASSROOM LEARNING ENVIRONMENT

Avi Hofstein

University of Iowa  
Iowa City, IA 52242

Ruth Ben-Zvi

The Weizmann Institute  
Rehovot, Israel

Rationale and Objectives

Getzels and Thelen (1960) presented a framework for the analysis of the school classroom as a unique social system. They suggested that classroom climate is a variable which can interact with, as well as predict, both achievement and attitudes of students.

An important contribution to the understanding of the role of the learning environment was made by Anderson and Walberg (1968) in which a measure of classroom social climate was developed and validated (L.E.I.; Learning Environmental Inventory) in connection with the Harvard Project Physics (Welch, 1973).

This study was conducted in order to investigate the assumption that student attitude and achievement in chemistry is related to, and can be predicted by their perception of the learning environment of their chemistry classroom.

Instruments and Methodology

A modified Hebrew version of the L.E.I. was used in this study. Whenever possible, a chemistry notation was given to the item, 13 scales (out of 15) were used: difficulty, speed, apathy, satisfaction, cohesiveness, disorganization, competitiveness, diversity, democracy, friction, goal direction, and favoritism.

In order to measure student attitude towards chemistry, the semantic differential technique was used (Osgood, et al, 1975). The inventory consisted of 20 (7 point rating) scales on the concept chemistry. The number of variables was reduced by a factor analytic technique. Four factors were extracted and used as measures of student attitude towards chemistry:

- Factor I -- Attractive and Exciting
- Factor II -- Clear and Understandable
- Factor III -- Necessary and Useful
- Factor IV -- Inexact and Confusing

The achievement test consisted of 25 multiple choice items designed to test students knowledge in chemistry at the end of the eleventh grade ( $\alpha$  Cronbach - 0.86).

The L.E.I., attitude and achievement test were given to 400 eleventh grade (age 16) students from 12 classes in eight Israeli high schools. All students were in their second year of chemistry learning, studying the same high school chemistry curricula.

#### Results and Discussion

In order to determine the association between the two sets of variables a canonical correlation analysis was conducted. Two significant canonical correlations were obtained 0.48 and 0.41 ( $p \leq 0.001$ ).

After rotation, these canonical analyses revealed the following pattern:

##### First Canonical Variate

##### Learning environment variables

|      |                 |       |      |                          |
|------|-----------------|-------|------|--------------------------|
| high | goal direction  | } ↔ { | high | attractive and exciting  |
| high | satisfaction    |       | high | necessary and useful     |
| low  | disorganization |       | high | clear and understandable |

##### Second Canonical Variate

|      |            |       |     |                          |
|------|------------|-------|-----|--------------------------|
| high | difficulty | } ↔ { | low | clear and understandable |
| high | friction   |       |     |                          |
| high | speed      |       |     |                          |

The two canonical variates obtained, support the assumption that certain aspects of the classroom learning environment can predict student attitudes toward chemistry.

A multiple regression analysis was used in order to determine the relationship between achievement as the dependent variable, and the L.E.I. scales as independent variables. The regression analysis implies that six scales of the L.E.I. (friction, competitiveness, diversity, apathy, difficulty and cohesiveness) account for substantial variance (about 25%) in the measure of student achievement in chemistry.

#### Summary

One of the most important goals of science education is the fostering of a positive attitude towards science as well as increasing student achievement. From the results obtained in this research, it seems that creating a positive classroom atmosphere can enhance student attitudes towards science and their achievement in science.

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STUDIES OF SCIENCE STUDENT ROLE SPECIFIC SELF-CONCEPT  
AND PERCEPTIONS OF BEHAVIOR

Ken Peterson  
Don Kauchak

University of Utah  
Salt Lake City, UT 84112

A series of studies assessing science students' role specific self-concept and perceptions of behavior was completed using a computer scored double Q-sort instrument. The Q-sort consists of 20 behavioral items which Ss sort first to describe ideal science student behavior and then again to describe themselves. Computer assisted scoring consists of rank order correlation coefficient between the two sorts (a measure of self-concept) and group profiles of mean item ranks. The sorts were administered to over 800 eighth, tenth, and twelfth grade science students in the U.S. and Israel.

Self-concept levels were found to vary by course, class success, gender, and individual classrooms at the end of courses. Tenth grade, (mainly biology students) had the lowest levels, with eighth graders and seniors having similar higher levels. The strongest relationship was found between class success, as measured by course grade, and self-concept. A nearly linear relationship was found, with self-concept increasing with higher letter grade. No statistically significant self-concept differences were found between genders. Significant differences were found among classes of similar grade level, course, gender and grade distribution. Israeli students were found to have significantly lower self-concept levels than their U.S. counterparts.

Statistical differences in the mean ranking of specific items for a posttest administration were also found between countries and according to course, success, gender and among similar classes.

The relationship between success and self-concept is to be expected. The variation among courses and aged could be explained by two factors: development and selection. The younger students base less of their self-concept on course success and take other factors into account. Sophomores regard grades more seriously, in terms of self-esteem, apparently as much as do the seniors. However, the seniors (mainly physics students) are a much more select group (both self- and institutional-selected) in terms of school success and aptitude. Perhaps some students are enabled to higher success by positive feelings of self, while other students' self-concept is nurtured by their success. Interviews might clarify these possibilities in terms of cause-effect.

While previous authors suggest that genders vary in attitudes about science, we found no significant differences. Perhaps the general more favorable attitudes of females to school work counterbalances some less positive science attitudes. Specific perceptual item differences in mean rank by gender, success, and course suggest that students do perceive classroom life and performance differently according to those factors. The between country differences may be explained more by cultural differences in criticism than by actual less good feelings about self.

Other results of significance to science teachers are that students continue to rank typical school work behaviors higher than science related behaviors. For example, the number one ranked item by every classroom on which data were gathered was "completes all homework." Items emphasizing inquiry were consistently ranked lower. At the same time, students ranked classroom environment and cooperation items highly.



EFFECTS OF TEST ANXIETY AND TESTING CUES  
ON SCIENCE TEST SCORES

William J. Kermis  
Larry E. Schafer

Syracuse University and  
Liverpool School District  
Syracuse, NY 13210

Objectives and Rationale

Two variables, test anxiety and testing cues, appear to contribute to science test performance. Hall and Hinkle (1972) maintain that many students fail tests because of the anxiety aroused by the presence of certain cues in the testing situation. Wine (1971) has suggested that the anxiety experienced by students depends on two variables: The general tendency to become anxious in a testing situation (trait-test anxiety) and the presence or absence of specific testing cues or stimuli. Wine has further suggested that high test anxious students (HTA) should attend to disruptive cues which interfere with test performance, whereas low test anxious (LTA) students should attend to helpful cues which facilitate test performance. Since a compilation of disruptive and helpful testing cues has only recently become available (Kermis, 1979), research examining the interaction between the trait of test anxiety and specific testing cues has not been performed. Hence, this study was designed to examine the influence of test anxiety (high and low) and testing cues (disruptive and helpful) on science test scores of geology students.

Methodology and Design

Subjects were 28 undergraduates enrolled in physical geology. An initial randomized design that was counterbalanced on test content and test form (disruptive and helpful cues) revealed that neither test content nor the order in which the form of the tests were administered (disruptive test before helpful

or visa versa) had any effect on subjects' performances. Therefore, the design was reduced to a "posttest-only design" (Campbell and Stanley, 1963), in which there were two levels of trait test anxiety (HTA and LTA) and two levels of testing cues (disruptive and helpful). Subjects were repeatedly measured, once on a test with disruptive cues and again on a test with helpful cues.

#### Instruments and Data

The State-Trait Anxiety Inventory (Spielberger, Gorsuch, and Lushene, 1970) was given to the students to classify them according to the trait of test anxiety (HTA or LTA). The different geology tests, with disruptive and helpful cues added (Kermis, 1979), were judged equivalent on the basis of content difficulty and scope by two independent experts. A 2 x 2 analysis of variance (ANOVA) for repeated measures was used (Bennett and Franklin, 1963). An alpha level of .05 was set for significance testing.

#### Results and Conclusions

The results of the 2 x 2 ANOVA (HTA and LTA X disruptive and helpful testing cues) revealed a significant test anxiety main effect [ $F(1,26) = 4.413, p \leq .05$ ] with low test anxious students outperforming high test anxious students. Neither the testing cue main effect nor the test anxiety X testing cue interaction were significant. The results support the hypothesis that high test anxiety retards performance. This implies that teachers should take every precaution to reduce test anxiety in their students. Since the constraints of the experimental setting precluded the use of the most disruptive and helpful cues (Kermis, 1979) the question for further research remains: Do HTA students attend to disruptive testing cues while their LTA counterparts attend to helpful testing cues?

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## CONCURRENT SESSION E

### Session E-2      Techniques and Procedures of Research

Topic:              Explained Variance: Its Importance and  
Techniques for Calculation

Ron Good

Florida State University  
Tallahassee, FL 32306

Knowledge of the magnitude of the effect(s) of an experimental study in science education should be of utmost concern to researchers in the field, but it is not being reported by the authors of papers in JRST. Working on the assumption that the reason for the failure to report the magnitude of effect(s) of experimental studies in JRST is a general lack of knowledge of its importance and how it can be calculated, this session describes the concept of "explained variance" in analysis of variance designs and then explains how it can be calculated and reported.

Reporting the magnitude of effect(s) of an experimental study in science education allows one to assess the practical significance of the research. Traditionally, reliability figures in the form of alpha levels (.05, etc.) and probability values (.25, .10, .05, .01, etc.) have been used in reporting the "significance" of a piece of experimental research. The limitations of this practice are easily seen when magnitude of effect(s) is considered.

Three indices for estimating magnitude of effect(s) are eta-squared, epsilon-squared, and omega-squared and in this session the last index is used in some detail to illustrate techniques for calculating its value in various ANOVA designs in science education research.

THE DEVELOPMENT AND VALIDATION OF  
A GROUP TEST OF LOGICAL THINKING

Kenneth G. Tobin  
William Capie

University of Georgia  
Athens, GA 30602

Purpose

The purpose of this study was to construct a pencil and paper measure of formal reasoning with high validity and reliability.

Procedures

Selected items from a test developed by Lawson (1978) were a basis for developing the initial version of the Test of Logical Thinking (TOLT). Two items were selected to measure each of five modes of formal reasoning: Proportional reasoning, combinatorial reasoning, probabilistic reasoning, correlational reasoning and controlling variables. The test incorporated demonstrations and students selected a correct response from a number of alternatives and provided written justification for their selection. The test was administered to a sample of 102 students in grades 8 through 11.

Although test reliability (Cronbach's  $\alpha = .74$ ) was reasonably high several factors were reducing validity. One concern was having students provide written explanations for the selected response. The test was modified so that multiple justifications were provided as well as multiple solutions for each problem. Reasons that had been volunteered by subjects on the first version of TOLT were modified and incorporated into the test. A correct solution required selection of the correct response and the best justification.

Video-taped demonstrations have minimized reading difficulties and created a standard administration procedure. Forty minutes are required to administer the test.

Evidence of concurrent validity was obtained from a comparison of TOLT performance by 25 college students with performance on 5 interviews designed to measure proportional reasoning, combinatorial reasoning, probabilistic reasoning, correlational reasoning and controlling variables.



An estimate of the predictive validity of TOLT was obtained from a sample of 222 students from grades 7 and 8 science classes. Performance on TOLT was correlated with science process achievement.

Factor analysis was used to obtain evidence of the construct validity of the test. TOLT scores from 22 students from grades 7 and 8 and 129 college students enrolled in introductory biology courses were used in the analysis.

The test reliability for TOLT and each 2 item sub-test was also estimated from the above data.

### Results

A correlation of .76 was obtained between TOLT scores and the number of interview tasks in which formal reasoning was used. When TOLT scores were used to categorize students as formal, transitional or concrete, 88 percent were classified at the same level of cognitive development as they were with the interview technique.

Thirty-five percent of the variance on a test of integrated science processes (reliability = .8) was explained by TOLT scores. Attenuation correction suggested a validity coefficient of .74.

Factor analysis indicated the presence of a strong factor that accounted for approximately 33 percent of the common variance. This analysis suggests an underlying dimension which was termed formal thought. Factor structure loadings of the test items ranged from .45 to .76.

TOLT reliability was .84 with  $\alpha$  values from .57 to .84 for the sub-tests.

### Conclusions

Evidence suggests that TOLT does measure formal thought. The reliability data are indicative of high internal consistency and the validity data are diverse and supportive of an effective group test of formal thought.

### Reference

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## A STUDY OF PERSONAL CHARACTERISTICS OF TEACHERS

J. William Byrd  
Charles R. Coble  
Carl G. Adler

East Carolina University  
Greenville, NC 27834

A problem of long standing in the preparation of new teachers is the early identification of those students who are most apt to make successful teachers. The importance of this task has been heightened in recent years with the advent of competency-based certification programs in North Carolina and other states. The question of competency measurement for experienced teachers is a difficult one, but the challenge of establishing the competency for certification purposes for new teachers is indeed thought provoking. The most common element in all of the studies on teacher effectiveness is the lack of agreement on any definitive statement characterizing a good teacher. This study took a somewhat different approach to this problem. Our objective was to identify any distinguishing characteristics that may be associated distinctively with those teachers judged to be successful by their peers and students. Our hope is that this information may be useful in providing clues to be used in the early identification of students who are apt to make good teachers.

The following data was collected in twenty-five (25) high schools in North Carolina:

- 1) peer evaluations consisting of teachers' evaluations of each other and the principal's evaluations of the teachers;
- 2) each teacher completed a Personal Orientation Inventory (POI);
- 3) each teacher completed a Personal Interrogatory Form (PIF), which was locally generated; and,
- 4) student evaluations for each teacher.

The resulting data set consisted of 25 principal evaluations of teachers, 95 teacher evaluations of teachers, 90 POI test results, 15 PIF test results, and 2,314 student evaluation forms.

The analysis of the data produced nonidentical successful teacher groups as judged by peer evaluation and by student evaluation. We then proceeded to study personal characteristics of successful teachers as identified by each of the two evaluating groups.

In many regards, the teachers appear to be very homogeneous in their characteristics. There were, however, characteristics which could be clearly identified with the successful teacher -- sometimes common to both peer-selected and student-selected groups of successful teachers and sometimes peculiar to either the peer-selected or the student-selected group. Characteristics common to both successful teacher groups included the following:

- 1) they subscribe to more professional journals;
- 2) did strive for good grades as a high school student; and,
- 3) appear to watch more television.

Characteristics common to the peer-selected group of successful teachers included:

- 1) they made better grades as college students; and,
- 2) their teaching methods include the use of more experiments, more demonstrations, more lecture, more small group activities and more small group discussions.

Teacher characteristics that are peculiar to the student-selected successful teacher group included:

- 1) they ranked higher in interpersonal sensitivity on the POI test; and,
- 2) their teaching method includes significantly more demonstrations, field trips, games, small group activities and discussion.

Interestingly, these teachers do less lecturing than the other teachers in the sample.

This report includes samples of all the instruments used in collecting data, a presentation of the data, a discussion of the analysis, and a more detailed presentation of the results.

FACTORS AFFECTING THE ACHIEVEMENT OF  
STUDENTS IN BLACK, SOUTHERN COLLEGES

Jane Butler Kahle

Purdue University  
West Lafayette, IN 47906

Bernice Coar Cobb  
Gwendolyn D. Wilson

Talladega College  
Talladega, AL 35160

Charlotte Carter

Miles College  
Fairfield, AL 35064

Mildred A. Collins

Stillman College  
Tuscaloosa, AL 35401

Barbara Sm. Morgan

Atlanta Jr. College  
Atlanta, GA 30310

Sandra E. Taylor

7160 Vernon Avenue  
University City, MO 63130

A panel of five minority educators will discuss their current research which investigates factors affecting science and mathematics achievement of minority students. Participants are drawn from colleges in the Alabama Consortium of Higher Education, and their research has been funded by the National Institute of Education grant, "Advanced Study and Research Skills in Science Education for Women Faculty at Minority Institutions," (NIE 780233). The feasibility of such research including practical and theoretical constraints;

a variety of instructional variables; and an assessment of some of the personal, sociological, and cognitive traits of minority students will be discussed.

The issue to which this symposium is addressed is the general one of appropriate education for minority students. The participants have joined in a research effort, conducted on four different campuses, to assess various student behaviors and characteristics which might affect their achievement. Samples have been drawn from both non-science and from science majors, and studies have been conducted in science and mathematics classes. Prior to the individual reports, general demographic data and descriptive statistics from the five studies will be presented.

The individual papers will each discuss one or more probable factors which may affect science achievement of minority students. The first participant will present an analysis of the use of Gowin's "V" during laboratory exercises (Novak, 1979). She will analyze its effect on biology achievement, attitudes toward biology, and perception of fate control (Rowe, 1978) among her first year, non-science major students. She will discuss utilizing her findings in a prediction formula to determining probable future success in science classes.

The second presenter will discuss her findings concerning possible interactions between cognitive style (Witkin, 1967), locus of control (Lao, 1970), and mode of instruction on the achievement of freshman biology students.

The third presenter will report her findings utilizing a population of science majors. She will assess any achievement and attitudinal differentials which accrue from utilizing individualized modes of instruction in biology.

The fourth researcher will report an analysis of the effect of spatial experience on the mathematics and science achievement of male and female minority students.

The last paper will discuss the possibility of predicting a student's locus of control orientation based on classroom observations. Correlation studies of this dimension with science achievement in black, Southern college student population will be presented.

Since each report composes one aspect of an overall study to determine factors affecting the achievement of students in Southern, minority colleges, interrelationships and comparisons between the studies will provide issues for discussion as well as questions for further research.



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THE EFFECTS OF TEACHERS' WAIT-TIME AND  
COGNITIVE QUESTIONING LEVEL ON PUPIL  
SCIENCE ACHIEVEMENT

Joseph P. Riley

University of Georgia  
Athens, GA 30602

Problem

Does teacher wait-time and cognitive questioning level effect pupil achievement?

Objectives

The objectives of this experimental study were to:

- 1) investigate the effects of wait-time of 1 second, 3 seconds and 5 seconds on primary and intermediate students' achievement;
- 2) compare the achievement scores of students who experienced science lessons containing either 100%, 50% or 0% high cognitive level teacher questions; and,
- 3) examine achievement results for possible interactions between wait-time and cognitive level of questions.

Theoretical Framework

The manipulated variables in this study, wait-time and cognitive level of teachers' questions, have been investigated separately in previous process-product research. The results of teacher questions on student achievement have been dissappointing. The research indicates that whether teachers use predominantly higher cognitive questions or predominatly fact questions makes little difference in student achievement (Winne, 1979). In the only reported study examining the effects of wait-time on achievement Tobin (1979) found that wait-time was significantly related to science achievement in grades 5, 6 and 7 in Australian schools.

The unsuccessful attempts of previous research to identify achievement advantages of higher cognitive questions over fact questions may be due in part to their omission of wait-time as an interacting variable. This study addresses this problem by combining wait-time with cognitive questioning level.

#### Design and Procedures

The available population consisted of all students enrolled in two elementary schools in Athens, Georgia. Groups of 5 subjects were randomly selected from 15 intermediate and 15 primary classrooms and assigned to one of three treatment levels resulting in an N of 150. The design of this study can be diagramed as follows:

R     $X_1$     $O_1$     $O_2$

R     $X_2$     $O_1$     $O_2$

R     $X_3$     $O_1$     $O_2$

With  $X_1$ --  $X_3$  wait-time/cognitive question treatments and  $O_1$  -  $O_2$  achievement tests with knowledge and above knowledge items respectively.

Thirty pre-service teachers conducted the treatment by teaching a thirty minute lesson in which the length of wait-time and percentage of higher cognitive questions were prescribed. The lessons were audio taped to insure fidelity to the scripted lessons. The content of the lesson was the same for each group. At the end of the lesson a criterion test was administered. This test was analyzed to insure adequate reliability and validity. Data were analyzed using multivariate analysis of variance (MANOVA).

#### Results

There was no significant overall question level effect ( $p \leq 0.15$ ). There was a significant overall wait-time effect ( $p \leq .01$ ). Students assigned to teachers using 5 second wait-time scored significantly higher than did those assigned to teachers using 3 and 1 second wait-time. These significant differences were found on the total achievement test and on the knowledge and above knowledge subtests. On the knowledge subtest students assigned to teachers using 50% higher cognitive questions scored significantly higher than those using a 0% higher cognitive level question ( $p \leq .05$ ). No significant interactions were found.

### Conclusions

The results of this study indicate that students' achievement at the knowledge and above knowledge levels of Bloom's Taxonomy (1956) can be increased by extending wait-time. The results imply that the optimum wait-time in terms of student achievement, occurs somewhere between 3 and 5 seconds.

Interpretation of the results imply that, in terms of student achievement, extended wait-time is as important for low level questions as it is for high level questions.

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A SUCCESSFUL TRANSPLANT OF WAIT-TIME  
AND QUESTIONING STRATEGIES TO CHILDREN'S  
ORAL LANGUAGE BEHAVIORS

Donni K. Hassler

American University  
Washington, DC

Edward R. Fagan  
Michael Szabo

The Pennsylvania State University  
University Park, PA 16802

Research on science teaching has drawn ideas and methodology from educational and psychological areas such as attitude development, research design, instructional systems, and information processing. The present study is a turnabout. It draws from an area heavily researched by science educators (wait-time) and applies it to a non-science area: Oral language behaviors in language arts.

The purpose of this study was to determine if the results Rowe found in science with wait-time utilization could be replicated in the language arts during children's literature discussions. Wait-time is defined by Rowe as being of two kinds:

- 1) Wait-time I, the pause after a teacher asks a question; but before someone is called on to answer; and,
- 2) Wait-time II, the pause after a student response, but before the teacher comments or calls on another student.

Each hypothesis was investigated to determine the effects and the interaction of the three independent variables: Wait-time, questioning, and wait-time and questioning upon the following six dependent variables:



- 1) length of student responses;
- 2) alternate student explanations;
- 3) higher-level student responses;
- 4) higher-level teacher questions;
- 5) teacher questions; and,
- 6) disciplinary moves.

This study was based on the posttest only control group design six by Campbell and Stanley (1963). The six dependent variables were statistically analyzed by using ANOVA. Twenty elementary school teachers from seven schools were randomly assigned to one of four groups: wait-time, questioning, wait-time questioning, and control. The teachers from the third, fourth and fifth grades were asked to hold 10 to 15 minute follow-up discussions for each of the seven children's literature stories. The seven stories were made into slide/tape presentations in order to insure consistent use of the stimulus. The first slide/tape presentation was considered trial-run to familiarize the teachers and students with the mechanics and procedures of the presentations.

The follow-up discussions were tape recorded by the teacher for data-gathering on the six dependent variables. Before the post-training, each teacher was asked to tape record two follow-up discussions from children's literature stories of their own choosing or from a suggested list in order to reduce the possibility of the Hawthorne effect.

The results of the study indicated:

- 1) the frequency of higher-level questioning and total teacher questioning were directly and significantly effected by wait-time utilization;
- 2) the frequency of alternate student explanations, higher-level student responses, and higher-level teacher questioning as well as the length of student responses were each directly and significantly effected by higher-level questioning utilization; and,
- 3) the frequency of alternate student explanations, higher-level student responses, higher-level teacher questions as well as total teacher questions were directly and significantly effected by the interaction of combined wait-time and questioning utilization.

In conclusion, the wait-time treatment alone did not provide the same results as Rowe experienced in science. In the language arts, the combined effects of wait-time and questioning training provided the most significant results for the dependent variables overall.

#### Reference

- Campbell, D. T. and Stanley, J. C. Experimental and Quasi-Experimental Designs for Research. Chicago: Rand-McNally and Co., 1963.

GENERAL SESSION III

Presiding: Stanley L. Helgeson

The Ohio State University  
Columbus, Ohio 43210

Topic: Research in Science Education: NSF

Speaker: Erik McWilliams  
National Science Foundation

Recent Trends in Educational Research  
of a Cognitive Sort

Speaker: Mary Budd Rowe  
National Science Foundation

Overview of Research on Participation  
in Science by Females and Minorities

Speaker: Andrew R. Molnar  
National Science Foundation

Research on Computing in Education

Speaker: F. James Rutherford  
Assistant Director for  
Science Education of  
National Science Foundation

Issues in Funding Educational Research

National Science Foundation  
Washington, DC 20550

## RESEARCH IN SCIENCE EDUCATION: NSF

### Recent Trends in Educational Research of a Cognitive Sort

Erik McWilliams

National Science Foundation  
Washington, DC 20550

At the NSF and elsewhere, there is steadily increasing interest in and support of research directed specifically into the mental processes and structures which underlie competence in some important area of science or mathematics. The focus of such research, namely the learning of science or mathematics, lies squarely in education. The methods and theories (when present) are for the most part psychological, with some clear influences from the field of computer science. Some researchers, particularly those with long-standing interests along these lines, are pleased with and optimistic about this trend; others are not.

### Overview of Research on Participation in Science

by Females and Minorities

Mary Budd Rowe

National Science Foundation  
Washington, DC 20550

The participation of females and minorities in science is less than would be expected. Some of the research provides a basis for understanding the factors that are involved. There are still many puzzling questions to be answered. For example, if curriculum is such a major factor, why are the differences between sexes on the NAEP science as pronounced as they are for 9 year olds? If English as a second language is a factor why is the performance of Hispanics on the NAEP science generally better than that of blacks? In the study of talented students in mathematics the pool of females is markedly increasing. It appears, in addition, that capability in mathematics is not a sufficient condition for success in physics for either males or females.

## RESEARCH IN SCIENCE EDUCATION: NSF

### Research on Computing in Education

Andrew R. Molnar

National Science Foundation  
Washington, DC 20550

The computer has been described as the new educational imperative. Higher education alone spends an estimated one billion dollars a year on computing. The computer, as a tool, as a medium, and as an object of study, now affects all aspects of modern education. But, what do we know of this new intellectual technology? How is it being used and what new research needs has it generated? A review will be presented of national studies, current trends, and a meta-analysis of the research literature on computers in education. Research on new innovative uses of computing and computer literacy efforts will be described. Recommendations of a task force on Technology in Science Education: The Next Ten Years will be discussed.

### Issues in the Funding of Education Research

F. James Rutherford

Assistant Director for Science Education  
National Science Foundation  
Washington, DC 20550

In trying to build a fruitful support system for research in education, a federal agency needs to confront more issues than simply how to identify the best research proposals from among those submitted. Some of these issues are: What is the proper balance between agency and field determination of funding priorities? How can stability of funding over time be achieved, while still retaining the ability to respond to compelling "research opportunities"? Should theory building or practical utility be favored in federally funded educational research? Given limited resources, should there be a funding bias toward individual researchers or toward ongoing research groups?



# A META-ANALYSIS OF SELECTED ADVANCE ORGANIZER RESEARCH

REPORTS FROM 1960-1977

M. James Kozlow

University of British Columbia  
Vancouver, B. C. V6T 1Z5

Arthur L. White

The Ohio State University  
Columbus, Ohio 43210

This is a report of a meta-analysis of selected advance organizer research reports. The study was undertaken because of the large amount of research in this area, and the general failure to reach any definitive conclusions from this research. The purpose of the analysis was to determine whether or not there were any characteristics of the experimental settings or materials in the 99 advance organizer studies analyzed that had consistent relationships with the treatment effects obtained through the use of advance organizers. The dependent variables used to represent the treatment effects were the t-statistic for the difference between means and the probability level of significance. The independent variables described characteristics of the sample, treatment administration conditions, type of subject matter, quality of the research procedures, and characteristics of the advance organizers and learning materials.

The data analysis involved the computation of descriptive statistics, the examination of the relationships between independent and dependent variables by correlation coefficients and stepwise multiple regression analysis, and the examination of the interrelationships among the independent variables by factor analysis.

Of the 99 t-statistics computed, 68 were positive. Nine of these were significant at the 0.05 level and 13 were significant at the 0.01 level. None of the 29 negative t-statistics were significant. These results indicate that there is a tendency for advance organizers to show facilitative effects.

Some of the significant findings in favor of advance organizers may have been due to the possible contribution of the advance organizer alone to answering the test questions or to an inequality of study time for the treatment groups. The influences of these variables on the relationships between the dependent and independent variables were removed by stepwise multiple regression analyses.



The relationship between type of advance organizer and the dependent variables was probably the most fundamental relationship identified. There was an indication that comparative advance organizers may be more effective than expository ones.

Student inability to understand the advance organizer information may account for some of the non-significant experimental findings.

There was an indication that advance organizers may become less effective as the learning materials become more complex.

The dependent variables had significant correlations with subject area, concept type, and grade level indicating that advance organizers may be less effective when the subject matter is science, more effective for classificational concepts, and more effective at the higher grade levels. A list of guidelines for future research on advance organizers was reported based on this analysis.

CONCURRENT SESSIONS F, G AND H

Sessions F-2, G-2 and H-2

Techniques and Procedures  
of Research

Topic: Estimating the Reliability of Classroom  
Observation Systems

William Capie  
Kenneth G. Tobin

University of Georgia  
Athens, GA 30602

Reliability estimates of classroom process variables can facilitate the critical interpretation of research designs and findings by those planning and reporting research as well as by consumers. This session will present several common reliability problems in classroom process measurement (e.g., temporal stability, interrater agreement) and present ways of measuring and interpreting the reliability.

Participants will receive sample data from studies or instrument development to determine appropriate analysis and then interpret the output from common computer programs. Sample sets of data have been selected to illustrate common methodological problems and decisions.

A COMPARISON OF THREE ESTIMATION  
STRATEGIES ON ESTIMATION SKILLS

Barbara J. Attivo

University of Pittsburgh  
Johnstown, PA 15904

The development of measurement and estimation process skills by prospective teachers is a prerequisite to the development of classroom teaching strategies for these processes. Limited empirical evidence exists in order to guide curriculum developers in the preparation of materials specifically designed to develop estimation skills. Current research frequently combines the measurement and estimation processes rather than focusing only on the estimation process.

This study addressed how the nature of estimation skill instruction affects prospective teachers' abilities to estimate metric length and area. Four types of estimation skills were identified by an estimation matrix which were based upon the physical absence or presence of the unit of reference during estimation and the physical absence or presence of the object to be estimated. Specifically, the investigation sought to determine what effect instruction for one type of length and area estimation skill had on the transfer to the remaining three types of estimation skills.

Instructional strategies employed were:

- 1) a personal reference unit;
- 2) a cut or drawn unit of reference which was put out of sight before making an estimate; and,
- 3) estimation without specifying an explicit strategy.

Ten hypotheses were tested relating to two questions.

- 1) Is one of the three instructional strategies more effective in reducing estimation error?
- 2) What effect explicit instruction to reach criterion for one type of estimation skill had on the ability to improve the remaining types of metric length and area estimation skills?

After a pretest, 126 subjects were randomly assigned to one of the instructional strategies. Utilizing self-paced instructional materials, students were instructed to criterion in one type of estimation skill for length and area. Criterion referenced mastery tests were administered after each instructional module. After instruction 93% of the students demonstrated mastery of length estimation skills and 81.7% of the students demonstrated mastery for area estimation skill. Upon achievement of mastery, a retention/transfer test was administered to determine the ability to perform the other three estimation types for which no instruction or practice was given.

Non-parametric statistical techniques were used to compare estimation error scores on the retention/transfer tests. Scores were compared for subjects instructed in the use of the personal reference measure strategy to the scores for subjects instructed in the use of the unit reference strategy and also with those subjects who were given no specific instruction in estimation strategy. The Wilcoxon-signed ranks test was used to compare estimation error scores before and following instruction for each of the instructional strategies for each estimation type.

As a result of testing the hypotheses, the following conclusions were reached:

- 1) The personal reference strategy was significantly more effective in the reduction of estimation error than the unit reference strategy for estimation skill of the same type as the instruction.
- 2) No significant differences were detected in estimation error when the personal reference strategy was compared with the strategy in which no explicit instruction was given for the estimation process.
- 3) Concerning the transferability of explicit instruction in one type estimation skill it was concluded that students who achieved mastery criterion during instruction on estimation skill showed a significant reduction in estimation error for two additional estimation skill types. Additionally, significant estimation error score reductions were noted for selected area estimation skills.

The results of the investigation could be employed by curriculum developers who desire to develop systematic instructions which will lead to the development of specifically identified types of estimation skills.

THE RELATIONSHIP BETWEEN THE SCIENTIFIC LITERACY OF  
SCHOOL ADMINISTRATORS AND THE PURCHASE OF SCIENCE TEXTBOOKS

Larry McKinney

Oklahoma State Department of  
Education and Moore Public Schools  
Moore, OK 73060

Rosalie M. Grant  
John W. Renner

University of Oklahoma  
Norman, OK 73019

If the curriculum is one of the major responsibilities of school administrators then to meet that responsibility, administrators must have an understanding of the nature of each of the disciplines which comprise the curriculum and of the ways in which students learn those disciplines. Textbooks form an integral part of the curriculum and their selection is another of the school administrators' responsibilities.

Role of OSTA in the Science Curriculum

In 1973, the Oklahoma Science Teachers' Association (OSTA) developed criteria to be used to examine science textbooks. A workshop for science teachers was sponsored and using these criteria, science teachers evaluated and rated science textbooks. The textbook ratings were compared with the science textbooks purchased by schools in 1974. Without exception, the books most highly recommended by the OSTA were not those most widely purchased by schools. Data for the OSTA textbook ratings and schools' purchases in 1977-78 revealed discrepancies similar to those found with the 1973-74 data. The greatest discrepancy in the 1977-78 data occurred with the elementary science textbooks.

Statement of the Hypothesis

The hypothesis investigated in this study was that school administrators having responsibility for selecting and purchasing



science textbooks, do not understand that science is a process of inquiry and that learning is best carried out through investigations. An inventory with a Likert-type scale was developed and tested to determine school administrators' attitudes towards science and science education.

#### Validity of the Instrument

Construct validity of the inventory was established asking 25 professors of science education to evaluate whether a set of inventory statements represented an inquiry or exposition view of science education. A point-biserial correlation analysis detected ambiguities in the inventory statements.

#### The Sample

The sample which responded to the attitude inventory consisted of 154 administrators of whom 34 were superintendents, 40 were high school principals, 20 were middle-junior high school principals, and 60 were elementary principals. A proportional random sampling technique was used for the study. The sample size was 10.8% of the total population. Sixty-five percent of the sample responded to the inventory. In addition to sampling school administrators, responses to the attitude inventory were obtained from 25 professors of science education.

#### Data Analysis

Two principle component analyses of the responses of administrators and of the science educators revealed that five factors accounted for 77% of the variance among science educators, but five factors accounted for only 55% of the variance among the school administrators. Analysis of the 13 statements which loaded on each of the five factors indicated that the science educators viewed science as process, that processes are basic to learning science content and fundamental to the way students learn. Administrators, on the other hand, regarded science as a content structured discipline rather than as process structured and that is is most effectively learned through lectures. Administrators observed science to have a laboratory component.

A one-way analysis of variance between each of the different administrator groups and the science educators indicated that there was a significant difference between the means of the groups.

### Results of the Study

The results of the study suggest that administrators view science as a lecture-laboratory discipline. They recognize processes used in learning science, e.g., observation and predicting, however when purchasing patterns of textbooks are examined those books which reflect science processes are not those selected. There is some indication that administrators know about science processes yet they cannot recognize the science process as it is related to the nature of learning and the approach textbooks use to promote the learning of science.

Administrators recognize the importance of collecting, interpreting and predicting from data but they do not understand the relationship these have to intellectual development.

COGNITIVE STYLE AND THE ACQUISITION AND TRANSFER  
OF THE ABILITY TO CONTROL VARIABLES

Barbara M. Strawitz

Louisiana State University  
Baton Rouge, LA 70803

Although teaching students to control variables is an important and pervasive goal of most elementary science programs, there is little evidence to indicate that successful instructional procedures have been devised to help teachers deal with the difficulties some children encounter in learning, retaining, and transferring this scheme. This is not to say that some of the training studies reported in the literature have not been effective, but only to suggest that perhaps the effects of instruction may best be understood by focusing attention on individual differences in learning and by looking at both retention and transfer as learning outcomes.

The purpose of this investigation was to study the effects of an instructional procedure designed to teach field dependent as well as field independent sixth graders to:

- a) control variables; and,
- b) transfer this ability to tasks differing from the training tasks.

The neoPiagetian theory of Pascual-Leone (1970) and an acquisition model for the control-of-variables scheme proposed by Case (1974, 1975) served as the framework for designing the instructional sequence.

Subjects in the study were sixth grade students judged by their teachers to be of at least average academic ability. Subjects were listed in rank order according to scores on a measure of cognitive style, then 56 from the extremes of the distribution were randomly assigned to an experimental or comparison group. Twenty-nine students, 15 field independent (FI) and 14 field dependent (FD) were assigned to the experimental group, and 27 students, 13 FI and 14 FD were assigned to the comparison group. All subjects were pretested with the bending rods task (Inhelder and Piaget, 1958) in individual interviews and three who

controlled all variables were dropped from the study. Students in the experimental group were individually instructed on controlling variables in three 25 minute sessions over a four week period. Students in the comparison group worked individually in an open-ended mode with the same materials as the experimental group in three 25 minute sessions. Approximately four weeks after the last training session, three posttest tasks were administered to all students. These tasks included the bending rods task used in the pretest and in training and two transfer tasks used to determine whether or not the students could apply what they had learned in new situations.

The Group Embedded Figures Test (GEFT) developed by Witken et al. (1971) was used as a measure of cognitive style. Controlling variables tasks were bending rods (Inhelder and Piaget, 1958), ramp (Wollman, 1977) and lever (adapted from Bredderman, 1973).

Dunn planned analyses (Marascuilo, 1978) were used to examine all pairwise contrasts, treatment effects, and treatment-cognitive style interaction effects for the mean number of variables correctly tested on each task. T-tests were used to test all contrasts except one where group variances were found to be unequal. In that instance  $t^*$  tests based upon the Welch-Aspin approximation to the t distribution were used.

The major findings in the study were:

- 1) There were no significant differences between or within groups on the pretest task.
- 2) Students in the experimental group correctly tested significantly more variables than students in the comparison group on the training and transfer posttest tasks.
- 3) Field independent students in the experimental group did not perform significantly better than FD students on the training and transfer posttest tasks, but a strong ceiling effect limited differences between subjects.
- 4) Field independent students in the comparison group performed significantly better than FD students on one of the transfer tasks (lever).
- 5) Field independent students in the experimental group performed significantly better than FI students in the comparison group on the training task (bending rods), however they significantly out-performed FD students in the comparison group on all posttest tasks (bending rods, ramp, and lever).



- 6) Field dependent students in the experimental group performed significantly better than FI students in the comparison group on the training task (bending rods), however they significantly out-performed FD students in the comparison group on all posttest tasks (bending rods, ramp and lever).
- 7) There were no significant treatment-cognitive style interactions on the training and transfer posttest tasks.

The results of this study indicate that FD as well as FI sixth grade students can be taught to control variables and to transfer this ability to novel tasks. Cognitive style, however, does seem to influence learning from a particular instructional method. In this study a method of instruction designed for FD students was also very successful for FI students, while a method allowing students to freely explore equipment without feedback was effective for only FI students.

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THE RELATIONSHIP OF PIAGETIAN MENTAL ATTRIBUTES  
AND THE DELAYED RECALL OF UNEXPLAINED  
CHEMISTRY TERMS PRESENTED IN A LECTURE

Deborah Jean Vojtko

University of Pittsburgh  
Pittsburgh, PA 15260

One of the major and frustrating aspects of science teaching is how students demonstrate learning through verbal discourse. Although models have been developed (Shavelson, Klausmeier, Anderson) none of these treat verbal terms at face value, as expressed by the student writer. Cunningham reviewed other models for measuring the retention of verbal learning substance but concluded they had less than acceptable validity, as would be found in similarity analyses for the meaning of terms.

A more contemporary approach is the use of words as a verbatim measure in analyses with statistics designed for this purpose (Ziccarelli and Moser, Modeling; Ziccarelli and Moser, NARST; Rojas and Rojas, Modeling). This study was done to examine:

- 1) the validity of this approach in concept learning and relationships with customary testing practices; and,
- 2) how the approach contributes to an understanding of a association-recall of verbal discourse.

The sample was 37 high school chemistry students (of two sections) who volunteered for the experiment. Comparisons of IQ and their course grades showed no significant differences between the group of 37 volunteers and the 22 students who did not participate.

The schedule was the presentation of a 15 minute lecture on the kinetic theory of solids during which the Ss were urged to take notes, administration of a ten item objective quiz (passive, four days later), a seven day delayed prose recall, and a 40 item objective test administered eleven days after the lecture. The lecture was rehearsed and designed to use 36 concept terms. It was taped to control for the use of the terms. The analysis was for these terms occurring in an immediate and one-week delayed prose recall cued by "recall what you heard in the lecture." The students were administered two Piagetian batteries of tasks after the experiment.

There were significant decreases in the frequency of the 36 terms used in one week recall passages, as compared to those of the immediate recall. An average 61% decay in term expressions occurred in that time of delayed recall.

The 12 terms of highest average frequency of recall during each recall trial were factor analyzed, with a principal components approach and the oblique technique of direct quartimin rotation (computer program BMDP4M, Dixon, 1975). Between five and seven factors were needed in explaining 70.0 - 80.4% of the variance. The primary psychological structure was terms describing kinetic theory; e.g., "close together, strong bonds, vibratory motion, gain or loss, and potential energy"; these were all delayed recall terms. The second factor was of the immediate recall terms of "sublimation, camphor, dry ice, and iodine." The three - five factor loadings were of immediate and delayed recall terms. The sixth factor was of the immediate recall terms of "solid-to-liquid, mole, solid-to-vapor", and the final factor was "sublimation" of the delayed recall. These results indicate that some association-recall retention learning occurred in the experiment.

The validity of verbal discourse in characterizing objective test performance was examined with discriminant analyses of high and low performance on objective tests on kinetic theory. Four terms in immediate recall significantly discriminated ( $p \leq .05$ ) above and below mean performance on the quiz administered four days later. The terms were: "solid, definite volume, noncompressibility, and potential energy." The canonical function correctly classified 87.5% of low scorers and 61.9% of the students earning above average scores. The canonical variate of immediate recall terms of "solid, properties, melting point, and crystalline" discriminated for test performance at the .01 level of significance. There were 86.7% of the low scorers and 81.8% of the group of students earning scores greater than the mean who were correctly classified by the group of terms.

Canonical and partial correlation analyses were computed for examining the role of association-recall for delayed prose statements. The 12 most frequently used immediate recall terms were identified as one set of variables. The terms of the delayed recall which had the greatest number of intercorrelations were identified as the second set of variables. Only three pairs of recall task terms, according to Bartlett's Statistic (computer program BMDP6M, Dixon, 1975), were needed to explain 59 to 72% of the delayed recall canonical variance with immediate recall terms after the removal of the linear dependence between the 12 delayed recall terms. The pairs of immediate and delayed recall terms, respectively, and in their order of importance were: "camphor and dry ice, melting point and solid-to-liquid, and weak vibratory motion and close together."

These results clearly indicate that after controlling for delayed recall of associated terms there is a set of immediate and delayed terms which have logical meanings regarding the principle of kinetic theory.

The results of these analyses demonstrate that the verbatim approach to verbal discourses validly describes the learning of concepts for the principle of kinetic theory. This conclusion is supported by the finding that words of high similarity of meanings are probably encoded into a logogen memory as proposed by Paivio (1971). This study is probably the first one which demonstrates a means for characterizing how students cognitively process scientific concept terms form a lecture into memory referents for a delayed retrieval in a verbal statement.

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CONCURRENT SESSION F

Session F-5

PANEL: ISSUES IN SCIENCE EDUCATION -- WOMEN IN SCIENCE

Panel Members:

|                                    |                                            |                                            |
|------------------------------------|--------------------------------------------|--------------------------------------------|
| Jane B. Bowyer                     | Marcia C. Linn                             | Elizabeth K. Stage                         |
| Mills College<br>Oakland, CA 94613 | Stanford University<br>Palo Alto, CA 92605 | University of Calif.<br>Berkeley, CA 94720 |

Speakers:

|                                                                                   |                                                                                                    |
|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Michele L. Aldrich                                                                | F. James Rutherford                                                                                |
| American Association<br>for the Advancement<br>of Science<br>Washington, DC 20550 | Assistant Director for Science<br>Education<br>National Science Foundation<br>Washington, DC 20550 |

In recent years women are entering the labor force in record numbers. Between 1950 and 1974 the number of male workers in the labor force increased by 25% while the number of female workers increased by 100% according to the U.S. Department of Labor. Meanwhile, over the last ten years there has been no change in the percentage of women participating in science or science related careers according to S. Astin. The number of programs available to increase the representation of women in science has increased dramatically during the past years. Why are women still underrepresented? What can we do to change that situation? The speakers in this panel will address these issues from a number of different viewpoints.

Dr. Michele Aldrich of the American Association for the Advancement of Science has been conducting a study of the projects on women in science, engineering and mathematics that have been conducted in the U.S. since the 1960's. Literally hundreds of projects have been instituted. Perhaps the best known have been those funded by the National Science Foundation including a visiting women's scientists program for high school, career information workshops for college level women and career facilitation projects for women



reentering science careers. Dr. Aldrich will discuss the implication of her findings and suggest directions for future projects to increase the representation of women in science.

Retaining women in science and science related programs is often a problem. Dr. Elizabeth K. Stage of the Group in Science and Mathematics Education, University of California, Berkeley, will summarize research and program activity aimed at increasing retention of women in science programs. She will describe successful institutional efforts and identify strategies that can be used by individual teachers of science to increase retention of women.

Recently research on gender related differences in attitudes and aptitudes has offered some interesting insights into the participation of women in science. Teacher awareness of and response to these differences will foster participation of women in science. Dr. Jane Bowyer, Mills College, will summarize research to date about gender related aptitudes and attitudes that are correlated with achievement in science. She will discuss teacher traits that have been shown to be conducive to encouraging female participation in science.

Dr. Marcia C. Linn, Stanford University, will discuss research on science concepts and problem solving. She will contrast areas where there are no gender differences to areas where gender differences exist in problem solving. Aptitude differences which relate to women's strengths and weaknesses in problem solving will be presented. Suggestions for research to identify aptitude treatment interactions follow from these findings.

The National Science Foundation is concerned about the representation of women in science. In addition to the women in science program described earlier, the science education directorate gives high priority to proposals in all their programs which incorporate a concern for the underrepresentation of women in science. Dr. F. James Rutherford, the Assistant Director of NSF for Science Education, will comment on the approaches that science educators could take to respond to the underrepresentation of women in science.



VERIFICATION OF A CAUSAL MODEL  
FOR STUDENTS' ACHIEVEMENT  
IN MECHANICS IN A COLLEGE PHYSICS COURSE

Audrey B. Champagne  
Leopold E. Klopfer

University of Pittsburgh  
Pittsburgh, PA 15260

Rationale and Objectives

The literature on physics education attests to the concern of both instructors and researchers for attaining better understanding of the variables which influence students' achievement in college physics courses. Among the contributing variables which have been suggested are the students' previously taken courses in high school science, previous mathematics courses in high school or college, the students' mathematics skills, their ability to think formally (as defined by Piaget), and their pre-instructional conceptions or misconceptions about physical phenomena. However, the interactions of and likely causal connections between these contributing variables have not been systematically investigated. The objectives of the present study were:

- 1) to construct a causal model for students' achievement in the mechanics segment of a college physics course;
- 2) to estimate the path coefficients which link the model's hypothesized variables (as listed above) that contribute to achievement; and,
- 3) to determine the extent to which the observations verify the causal model.

Methodology and Design

This study utilized the methodology of explanatory observational research. In this approach, a theoretical causal model is postulated which includes both established and hypothesized causal relationships among the variables under investigation. These relationships are expressed in terms of structural equations, and the causal model can be represented in a path analysis diagram. When observational measures have been obtained for all

the variables in the causal model, appropriate statistical procedures are applied to establish the plausibility of the causal model and estimate the degree to which the various explanatory variables influence the dependent variable. In path analysis the interrelationships between the variables are examined by a series of regression analyses, from which the path coefficients can be estimated.

In the present study, the causal model's explanatory variables were those variables which previous research suggested as contributors to students' achievement in mechanics, the dependent variable. The subjects were 110 students enrolled in an introductory college physics course. Data were collected from questionnaires, three pre-instructional instruments, and mechanics achievement tests. The path coefficients obtained from the regression analyses indicated the strengths of the links between the observations of the explanatory variables and the students' mechanics achievement scores.

#### Instruments and Data

Profiles of each student's previous science and mathematics courses in high school and college were derived from questionnaires. In addition, each student completed three pre-instructional instruments:

- 1) a written test of mathematics skills;
- 2) a written test of the student's ability to think formally; and,
- 3) a test to determine the student's misconceptions about moving objects.

For this third test, the students were shown objects in motion under several different conditions and were asked both to describe what they observed and to interpret their observations. The students' written observations and interpretations were analyzed to identify mis-observations that they reported and misconceptions that they applied to their interpretations of the eight different conditions they observed. All these pre-instructional instruments yielded numerical data. The students' mechanics achievement scores consisted of the sum of standardized scores from two mid-semester examinations and the mechanics segment of the final examination.

#### Results and Conclusions

The causal model postulated a relationship between the amount of high school science taken by students and their ability to think

formally. It also postulated a relationship between having taken high school physics and both the students' ability to think formally and the correctness of their conceptions of moving objects. The amount of high school mathematics taken was causally related in the model to both the amount of college mathematics taken and the students' tested mathematics skills. Moreover, the causal model directly related four variables (i.e., having taken high school physics, mathematics skills, formal reasoning, and conceptions of motion) to the mechanics achievement scores. The strongest direct relationship was observed between mathematics skills and mechanics achievement, for which a path coefficient ( $p$ ) of 0.33 was obtained. Strong relationships also were observed between mechanics achievement and both correct conceptions of motion ( $p = 0.24$ ) and formal thinking ability ( $p = 0.23$ ), but only a weak direct relationship between mechanics achievement and having taken high school physics ( $p = 0.04$ ) was observed. Moderate relationships, with path coefficients ranging between  $p = 0.06$  and  $p = 0.11$ , were observed between amount of high school science taken and formal thinking ability, between having taken high school physics and formal thinking ability, and between amount of high school mathematics taken and mathematics skills. Path coefficients between all other pairs of variables were 0.03 or less, indicating very weak or no links.

It was concluded that the postulated causal model was generally verified by the observations of the explanatory variables. The main modification which the results suggest is that having taken high school physics is not directly related to mechanics achievement in a college course. However, this explanatory variable does have a moderate effect on students' formal thinking ability, which in turn influences mechanics achievement to some extent.

INTERACTIVE INSTRUCTIONAL VIDEO-TAPES, SCHOLASTIC  
APTITUDE, COGNITIVE DEVELOPMENT AND LOCUS OF  
CONTROL AS VARIABLES INFLUENCING SCIENCE ACHIEVEMENT

Russell H. Yeany  
Edwin A. Helseth  
William E. Barstow

University of Georgia  
Athens, GA 30602

Achievement in the sciences varies greatly across university students. This variation is contributed to and is influenced by many variables. Some of these variables can be manipulated and are more or less under the control of the instructor. Others are personalological variables which are not manipulatable but need to be identified and recognized for their influence on achievement. Bloom (1976) recently hypothesized that more learning is influenced by a student's entry characteristics than by variations in teaching. The two purposes of this study were to:

- 1) examine the relationships between university students' entry characteristics and achievement in biological science; and,
- 2) to assess the effectiveness of interactive instructional video-tapes in improving science achievement.

The variables which were judged most likely to be predictors of achievement because of the nature of the subject matter or instructional conditions were scholastic aptitude (quantitative and verbal), cognitive development and locus of control (other variables were included and will be mentioned in the expanded report).

#### Design and Procedures

As mentioned above, part of the study examined the effects of a manipulated variable; therefore, an experimental design was employed. It can be depicted as follows:

$$R \quad O_1 \quad O_2 \quad O_3 \quad X_E \quad O_4$$

$$R \quad O_1 \quad O_2 \quad O_3 \quad X_C \quad O_4$$



where:

- $O_1$  = SAT Scores (verbal and quantitative)
- $O_2$  = Cognitive Development Level
- $O_3$  = Locus of Control
- $X$  = Treatment Conditions
- $O_4$  = Achievement of Genetics Concepts

Other achievement data were collected at three points in the study before the implementation of the experimental design. These data were used in the regression analysis to measure the influence of the entry variables.

The experimentally accessible population was 120 freshman biology students at the University of Georgia. All students met in a single lecture section three days per week and in six different lab sections one day per week. Data were collected on all students. Randomization procedures were used to assign subjects to experimental or control conditions. The treatment was conducted during the genetics unit and consisted of video-tape instruction where the students individually used a guided problem-solving manual while viewing the tape. A concept was first presented and then the student was required to solve a related problem while the tape delayed for a prescribed length of time before the next concept was approached.

#### Data Collection

Data on all achievement variables were collected with multiple-choice objective referenced tests. All items had been piloted previously. Item and test analyses were used to establish reliabilities and objective-item matching by judges was used to ensure content validity. A total of four achievement tests were administered; one as a measure of treatment effects and three as measures of the influence of entry characteristics. Data on the entry variables were collected through standardized tests or from student files.

#### Results of Data Analysis

Data on all dependent variables were analyzed using regression analysis and a general linear model program.

The results indicated that the instructional interactive video-tape did significantly and positively influence achievement on the genetics concepts. The increase in achievement amounted to approximately 6%. The entry variables also proved to be significant predictors of success on all achievement measures which individually predicted as much as 39 and 47 percent of the variance in achievement. In all cases these were better predictors



of achievement than any other entry variables. On all the achievement variables, three or four factor models predicted as much as 60 percent of the variance in science achievement.

### Conclusions

Regression models based on entry characteristics of students can be developed which will significantly and consistently predict achievement variance. It is also possible to influence science achievement through the use of interactive instructional video-tapes. The former results support the recent contentions of Bloom; but, the latter results show that instructional intervention can still be a significant factor in influencing science achievement.

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THE INTERRELATIONSHIP BETWEEN PROPORTIONAL REASONING,  
VISUAL SPATIAL ABILITY AND SEX

Sharon Brendzel

Rutgers University  
New Brunswick, NJ 08903

Proportional reasoning is necessary in science, math and in related areas, as well as in everyday experiences.

Schonberger (1976) has shown a relationship between visual spatial ability and mathematical problem solving. A number of other studies have indicated a relationship between visual spatial ability and mathematical ability and between visual spatial ability and certain physical science careers. Indeed, Julia Sherman (1967) has suggested that sex differences in various aspects of intellectual functioning may be related to spatial perception. In studying the source of sex related differences in mathematics performance Fennema and Sherman (1978) found that results differed by school. The purpose of this study was to investigate the relationship between proportional reasoning and visual spatial ability.

In order to study visual spatial ability in relationship to proportional reasoning and school differences, visual spatial tests from the ETS Kit of Factor Referenced Cognitive tests were administered to approximately 200 high school students in grades nine and eleven. These students were also given written proportional reasoning tasks (similar to tasks of Karplus) and verbal comprehension tests. From this group of students, approximately eighty students (forty with a high visual spatial ability and forty with a low visual spatial ability) were selected to be tested with Witkin's Group Embedded Figures Test.

The results indicate significant sex differences in three out of four of the written proportional reasoning tasks and in the Piagetian balance, with males performing better. In these same tasks eleventh graders performed significantly better. Significant differences were also found between the two schools on these written proportions, on the Piagetian balance, on the GEFT, and on two out of five of the visual spatial tasks.

High correlations were found between the balance and written proportions, and between proportions and visual spatial tests, whereas correlations between verbal comprehension and proportions were considerably lower. The PSAT score correlations also broke down into two categories: the GEFT, proportions, and visual spatial tests correlating more highly with the math scores; and the verbal comprehension tests correlating more highly with verbal scores.

To summarize, the results indicate:

- 1) a relationship between visual spatial ability and proportional reasoning;
- 2) sex differences in proportional reasoning but not as clearly in visual spatial ability;
- 3) differences between school populations in proportional reasoning; and,
- 4) a relationship between visual spatial ability and PSAT math scores.

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IDENTIFYING ASPECTS OF COGNITIVE STYLES AS A PREREQUISITE  
TO INTERPRETING TEST SCORES

Dorothea Grimes

Rutgers University  
New Brunswick, NJ 08903

Test scores are broadly accepted as a measurement of some cognitive ability or skill. Within the classroom setting many situations call for testing where the test score is often used to detect a student's lack of concept attainment.

This research interprets test scores on a three-term series task by isolating and identifying individual strategies adopted by subjects. We have found strong evidence of two consistent individual preferred ways of organizing information on the three-term series task. Introspective reports were collected from subjects after the task was completed. Two distinct habitual modes of problem-solving were identified for the majority of subjects. One group of subjects spontaneously chose a (Concrete) properties approach of assigning physical properties to objects used in the task. A second group chose an (Abstract) directional method of representing the objects in the problem along some abstract imaginary scale. The Concrete properties group made more errors than did the Abstract directional group. Also, differences in performance on specific dimensions of the task as well as performance on certain measures of spatial ability could be accurately predicted for both groups. Although it might be expected that both strategies would have allowed for accurate completion of the task under non-speeded conditions, our tasks, as are most test-like situations, were administered under highly speeded conditions.

These results suggest that test scores may be a reflection of an individual's strategy selection and not a true indication of lack of concept attainment. Greater emphasis might therefore be placed on identifying aspects of "cognitive styles" as a prerequisite to interpreting test scores.



SPATIAL-VISUAL ABILITY AND SUCCESS IN EARTH SCIENCE IN  
HIGH SCHOOL AND COLLEGE

Gayle Henkin

Rutgers University  
New Brunswick, NJ 08903

With the renewed interest in the study of abilities and conditions which facilitate learning in schools arises a resurgence of research interest in the construct of spatial-visual ability. Spatial-visual ability spans the gap between cognition and perception. It is widely postulated that a major component of the conceptualizations of natural science rests within the domain of the spatial-visual. To what degree success in science is dictated by spatial-visual ability remains an open and crucial question.

A major contribution to this field of work is the body of literature on field independence developed by Witkin, Goodenough and their associates. Witkin showed that among college students, those who are field independent achieve higher grades in mathematics, science, engineering and architecture than those who are field dependent.

One part of the construct of spatial-visual ability concerns the facility with which one can extract and use simple patterns from within more complex designs. This operation is termed restructuring; the research instrument used to measure this operation is the Embedded Figures Test. The current study uses students' ability to restructure as a tool to predict achievement in specific science classes at the high school and college level. The test population consists of two groups of science students, 100 ninth graders enrolled in earth science and 65 college sophomores enrolled in a map reading class. Both groups took the group form of the GEFT before they studied a unit on contour mapping. Their scores on the GEFT were correlated with their scores on the achievement tests covering contour mapping.

It is hypothesized that students who are strongly field independent will score higher on the contour mapping test than their field dependent colleagues both in the high school group and the



college group. Superior restructuring skill should facilitate academic success. The phenomenon should be stronger in older students where the spatial-visual skills may be more consolidated. Furthermore the GEFT will show that fewer high school students are skilled at restructuring.

The results for young high school students suggest that the restructuring measure is moderately predictive of success in earth science ( $r = .25$ ). By contrast college sophomores differ widely in their restructuring ability both from high school students and from each other. Although there seems to be no predictive relationship using this measure for college women, for college men the relationship is significant at the .05 level,  $r = .33$ . Among the field independent men the restructuring measure predicts grade very strongly,  $r = .93$ ,  $p < .001$ .

These results seem to suggest that the restructuring ability is not as highly developed in the high school years as it is in a college age population. It would thus appear that the high school may indeed be the appropriate place for effective intervention to develop greater spatial-visual capacity. Although this is a highly speculative notion, effective intervention aimed at the spatial-visual capacity could be a link to more effective science education.

PROPOSITIONAL LOGIC AND ASYNCHRONOUS  
DEVELOPMENT IN SCIENCE EDUCATION

Geraldine J. VandenBerg

Somerset County College  
Somerville, NJ 08876

During the time we have students in our educational system, they develop through various cognitive stages, as defined by Piaget. The thought processes required in science have been linked with those defined by Piaget's formal level of operations, which is characterized by abstract thought. However, the nature of science education in the United States, even at the middle schools and below, is to try to teach concepts that are very abstract. This, as a review of the literature tells us, is not possible if the students are not at the formal level of thought, particularly in science oriented courses.

It, therefore, behooves us to diagnostically determine at what level students are before we attempt to present these abstract concepts. It would also be important to determine:

- 1) how we can enhance these formal operational reasoning abilities; and,
- 2) what is their pattern of development?

According to Piaget, these formal operational schemes develop in synchrony.

Sixty-six subjects ranging in age from 13 to 23 years, drawn from a heterogenous population, were tested. A propositional logic test. Consisting of disjunction, implication, and biconditional statements was developed and validated. In addition, thirteen formal reasoning tasks, nine clinical and four paper and pencil, were used. These assessed either the scheme of correlations, combinations, proportions, or probability. The test/tasks were individually administered in a randomized sequence.

The results show that propositional logic is positively related to ability in the formal operational schemes. The Pearson correlations indicated that the relationship is stronger for the schemes of correlations ( $r = .54$ ), probability ( $r = .63$ ), and proportions ( $r = .39$ ) than for the scheme of combinations ( $r = .22$ ) (all  $p \leq .04$ ).

Chi-square analyses revealed that propositional logic is necessary in solving correlations and probability tasks, may be helpful in solving proportions tasks, and not necessary in solving combinations tasks,

Additionally, three hypothesized hierarchical models of the correlations, combinations, proportions, and probability schemes were examined using ordering theory. The prerequisite relations among the schemes were determined by utilizing the response patterns of the subjects. It was determined that both the schemes of proportions and combinations are prerequisite to the scheme of correlations and to the scheme of probability. Furthermore, the results indicated that the correlations and probability schemes develop independently.

One outgrowth of this research might be to determine how the thought process defined by propositional logic develops. Perhaps there is a critical time when we could focus on these logical operations of propositional logic in order to induce their development. If ability in propositional logic is in fact a significant ingredient in formal reasoning, then in turn, formal level reasoning would be enhanced.

In addition, it would seem that if there is a hierarchical relationship among the formal operational schemes, then further research should be designed such that each of the formal schemes is assessed individually. Otherwise, it is quite possible that accurate results would not be established.

THE EFFECTS OF EXPERIENCE BACKGROUND AND AN ADVANCE  
ORGANIZER ON ELEMENTARY PUPILS' UNDERSTANDING  
OF SELECTED SCIENCE CONCEPTS

Exyie Ryder

Southern University  
Baton Rouge, LA 70813

Burton E. Voss

University of Michigan  
Ann Arbor, MI 48109

This study was undertaken to:

- 1) determine whether specific experiences in the pupils' background significantly influence the ability to understand two concepts on air pressure; and,
- 2) investigate the effects of an advance organizer on the pupils' ability to understand the two concepts.

It was hypothesized that previous exposure to certain relevant experiences would enhance the ability to master the concepts involved in the study, whereas a lack of exposure to these experiences would be a disadvantage to the learner. A background "Experience Inventory," developed by the investigator, was administered to a group of 401 third and fifth graders of diverse experience backgrounds. On the basis of the information obtained on the Inventory, a sample of 80 pupils was selected, representing 40 with "good" experience backgrounds and 40 with "poor" experience backgrounds. Other variables on which the sample was equated were grade, sex, and treatment. Assignment of pupils to the first three categories was fixed, while placement into the treatment groups was random.

The experimental treatment was based on David P. Ausubel's subsumption theory, which states that the understanding of new learning materials can be facilitated if the learner has available to him, in advance, a very general, abstract, and inclusive statement which subsumes the new and more specific content to be learned. Such a statement enables the learner to easily and meaningfully assimilate the new information.

A demonstration-interview was conducted, individually, with every child in the experimental and control group, at which time four demonstrations were performed. Prior to observing the demonstrations, pupils in the experimental group were read a 260-word conceptual passage, called an "advance organizer." The organizer contained background information considered necessary to promote the understanding of the two concepts on air pressure. The control group did not receive the organizer.

An achievement test, designed to measure pupil understanding of the two concepts, was administered on the third or fourth day following the demonstration-interview. Three levels of cognitive behavior were measured: knowledge, comprehension, and application.

The findings revealed that grade, sex, and treatment significantly affected pupil understanding of the two concepts, and that experience background had no statistically significant effect. Statistically significant results were also found for the interaction of grade and treatment. It was determined that the experimental treatment caused the greatest variation in achievement test scores. Achievement was highest for fifth graders, males, and for those pupils identified as having "good" experience backgrounds prior to participating in the study.

It was concluded that:

- 1) the advance organizer is most advantageous to pupils with rich experience backgrounds;
- 2) the advance organizer approach is a potentially effective instructional tool for relating the content of "advanced" subject matter to elementary school children;
- 3) elementary school children in grades three and five are able to grasp the concepts on air pressure, most effectively, at the "knowledge" level of cognition; and,
- 4) some experiences engaged in by the children are significantly related to the understanding of the concepts on air pressure.



ANALOGICAL REASONING, LOGICAL REASONING,  
AND FORMAL OPERATIONAL THOUGHT

Morris A. Enyeart

Rutgers University  
New Brunswick, NJ 08903

Objectives and Rationale

Researchers investigating the cognitive aspects of analogical reasoning often disagree about the nature of the relationship between that type of thought and Piagetian operational thought. Contrary to those who report that analogical reasoning requires only concrete operations is a group, which includes Piaget, that contends an individual must be formal operational in order to engage in analogical thought.

It seems reasonable to propose that if analogical reasoning is indeed related to formal operations, we should be able to intervene on certain thought processes known to be associated with that level of thought and observe predicted changes in analogical reasoning ability. This study was designed to test that proposal.

Methodology and Design

The non-random sample consisted of 72 students enrolled in an introductory logic course at a large eastern university. A pretest-intervention-posttest experimental design was employed with training in propositional logic being the independent variable and analogical reasoning ability the dependent variable.

Instruments and Data

The pretest data included non-clinical tasks to establish the degree of formal operations possessed by subjects (Lawson, Karplus, Adi, 1978); verbal and numerical analogical ability (Lunzer, 1965); Group Embedded Figures Test for field dependence-independence; propositional logical ability; and SAT verbal and math scores. Subjects were posttested on propositional logical ability and analogical reasoning ability. Course achievement scores were also considered a part of the post-test data.

Statistics from the SPSS program that were used to analyze the data were correlations, t-tests, factor analysis, and multiple regression.

### Results

- 1) Pretest measures of formal operations were significantly, positively correlated with both analogical reasoning ability and propositional logical ability ( $p \leq .001$ )
- 2) Pretest measures of propositional logical ability and analogical reasoning ability were significantly, positively correlated ( $p \leq .007$ ).
- 3) The mean posttest scores on both the propositional logic test and the analogical reasoning test were significantly higher than the pretest scores on the same measures.
- 4) For those subjects showing growth on the propositional logic test and the analogical reasoning test, that growth is related to the subject's score on the Piagetian measures.

### Conclusions

By intervening on specific thought processes known to be associated with formal operations, it was possible to show a resultant increase in analogical reasoning ability. In addition, corresponding increases in analogical reasoning ability and propositional logical ability were greatest in subjects that exhibited the greatest degree of formal operations on the pretest measures. Clearly, if analogical reasoning did not require formal operations, these results would not have been likely to occur.

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## ASSESSING THE QUALITY OF PRIOR LEARNING

Pinchas Tamir

Hebrew University  
Jerusalem, Israel

### Rationale and Objectives

The common way to assess the quality of prior learning is by immediate achievement tests. Sometimes, especially in research studies, retention tests are administered usually a few weeks after the completion of the course. While both achievement and retention tests are necessary and valuable, they have serious limitations as far as being indicators of the quality of learning. Therefore, many may agree with Ausubel (1968) that "perhaps the most valid way of testing for organizational strength and viability of knowledge...is to measure retention in the context of sequential learning in situations where the ability to learn new material presupposes the availability of the old." Ausubel suggested two approaches to the measurement of the "aptitude for further learning" (Cronbach, 1963), or viability of knowledge:

- 1) Transfer retention tests, which require students to study an unfamiliar new learning passage that is sequentially related to and presupposes knowledge of previously studied material.
- 2) Long term transfer paradigm, in which the aptitude of students for further learning in a particular field is assessed by measuring their achievement in the subsequent learning tasks, and by relating this achievement to their prior learning experiences.

The purpose of this study is to:

- a) demonstrate how the suggestions of Cronbach and Ausubel can be implemented in schools;
- b) describe a new instrument, the Prior Knowledge and Learning Inventory (PKLI) and its potential usage;
- c) demonstrate the validity of PKLI; and,
- d) introduce the concept of Retrospective Curriculum Evaluation.

## Method

The subjects of the study were 116 biology majors enrolled in first year college biology at the Hebrew University, Jerusalem. Their distribution according to their high school program was: 35% studied the old coventional curriculum, 47% studied the Israeli BSCS adaptation and 18% a combination of both. The different questionnaires and tests were administered as part of the routine procedures of the college biology course, by the course instructors. The following instruments were used:

- 1) Background questionnaire which ascertained the nature of high school experiences;
- 2) Prior Knowledge and Learning Inventory (PKLI) was designed according to a framework suggested by Tamir and first reported by Young and Tamir (1977). The inventory consists of a list of concepts or skills which is usually prepared by the course instructor. For each item (concept or skill) the students are asked to make two independent ratings, one for each of the following:
  - a) Degree of Knowledge Scale:  
This is a 5 point scale in which:
    - 1 = I don't know, don't understand cannot do.
    - 2 = I am not sure if I know, or understand, or can do.
    - 3 = I think I know what it means, I think I can do.
    - 4 = I know, understand, can do well.
    - 5 = I can explain, show how to do, to others.
  - b) Prior Learning Scale:  
This is a 2 point scale in which:
    - 1 = I have not learned this.
    - 2 = I have learned this.In the present study a list of 86 concepts and 15 skills was included. The background questionnaire and PKLI were administered in a special orientation meeting 4 weeks before the beginning of the course.
  - c) Achievement Test:  
Final examination consisting of 60 multiple choice items with KR20 reliability of 0.86.
  - d) Perceived Difficulty and Interest Questionnaire: (PDIQ)  
consisting of a list of topics included in lectures, laboratories and group discussions. The students were asked to indicate for each item on a 5 point scale (a) the perceived difficulty, (b) the degree of interest.



The last two instruments were administered at the end of the course. The data was analyzed by computer programs yielding frequency distributions, means, standard deviations, correlations, t-tests and analysis of variance.

#### Results and Conclusions

- 1) The study demonstrated the feasibility of measuring prior learning and prior knowledge as a routine procedure in any course.
- 2) PKLI was found to be a valid and reliable measure of prior learning and prior knowledge of concepts and skills.
- 3) Knowledge at the entry to the university was found to be positively correlated to the nature and quality of learning biology in high school.
- 4) Achievement in college biology was significantly correlated to prior knowledge, prior learning, and the nature of the high school curriculum.
- 5) Perceived difficulty and interest were significantly correlated to high school experiences, prior learning, and achievement.
- 6) The results indicate that the inquiry oriented BSCS curriculum in Israel provided meaningful learning experiences which had substantial long term effects and gave significant and considerable advantage to students in their university studies.
- 7) Retrospective evaluation, built on sound theoretical ground, adds an important dimension to the field of curriculum evaluation.

The potential of PKLI for guidance, consultation, instruction and evaluation is discussed in the paper.

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AN INVESTIGATION OF THE ACCEPTABILITY OF MARINE EDUCATION  
CURRICULA IN ELEMENTARY SCHOOLS IN MAINE

John W. Butzow

University of Maine  
Orono, ME 04469

Harry H. Dresser

Gould Academy  
Bethel, ME 04217

This study attempted to identify differences which existed in a number of variables among schools which accepted, rejected, or made exploratory use of an innovative marine education curriculum. The curriculum material consisted of one instructional unit (teacher's guide) each for grades K-8. Each of the units had an aquatic, or marine focus, and each was an infusion unit. That is it was intended to provide classroom teachers with exercises and activities related to marine, or aquatic topics for use in teaching in their standard grade-level disciplines.

The selected variables for this study were percentage of male teachers on a school staff; percentage of teachers by age categories on a school staff; percentage of teachers with academic preparation in mathematics, science, and social studies on a school staff; school pupil to teacher ratio; school total number of professional staff members; community per pupil expenditure; community socioeconomic status; and the number of highway miles from the community to the marine environment. Organizational Climate Description Questionnaire (OCDQ) openness scores, the eight subtest scores, and school climate type by Halpin and Croft's prototypic categories were also considered.

Principals of 64 Maine elementary schools provided some of the necessary demographic data, and administered the OCDQ to their teachers following prescribed guidelines to insure anonymity. At the same time, marine education infusion units produced by the directors and staff of the Northern New England Marine Education Project were distributed through the principals to the teachers of the schools. At the end of a six-week study period, the principals provided data on the use made of the marine education infusion units by the teachers in their schools. From this reported

use, the schools were categorized into accepting schools, rejecting schools, and schools which made exploratory use of the introduced innovative material.

The variables of teacher preparation in mathematics, and teacher preparation in science were found to be significant variables at, or beyond, the .05 level of significance by a one-way analysis of variance. Schools with higher percentages of teachers with academic preparation in mathematics and science were more likely to explore, or accept the innovative marine education material than were schools with lower percentages of such teachers.

T-tests showed highway miles from the marine environment and percentage of upper white collar workers in the community to be significant variables among accepting, rejecting, and exploring schools.

RELATIONSHIPS BETWEEN STUDENT ATTITUDES TOWARD SELECTED  
ENERGY ISSUES AND STUDENT PERCEPTION OF THE QUALITY  
OF THREE PEEC ENERGY EDUCATION UNITS

Lynn W. Glass

Iowa State University  
Ames, IA 50011

Helenmarie Hofman  
National Science Teachers Association  
Washington, DC 20550

The challenge of an ever increasing energy consumption rate will need to be met from several fronts if our nation is going to continue to prosper as we have known it. One of the major fronts to meet this challenge is through the educational system with high quality curriculum materials and excellent teaching. The specific objective of this study was to:

Collect data from students in a field test of three Project for an Energy Enriched Curriculum (PEEC) draft units that would permit making rational decisions about the final form of the three units.

The Project for an Energy Enriched Curriculum is being developed by the National Science Teachers Association under contract to the United States Department of Energy. The three units, Coal, Energy for the Future, and Exponential Growth, were designed by the PEEC staff with concurrence from the broad-based PEEC steering committee. Teachers were selected in a national competition to write the units based upon the quality of an energy lesson plan they submitted. The teachers met in the summer of 1978 on a college campus where they had access to the necessary scientific and technical expertise to write the units based upon the outlines previously developed by the PEEC staff and steering committee.

Teachers who had participated in a National Science Foundation Energy Education workshop volunteered to field-test the material. Five teachers and 234 students participated in the field test of Coal, six teachers and 221 students field-tested Exponential Growth, and two teachers and 171 students field-tested Energy for

the Future. All students were in grades seven through twelve. Teachers maintained a daily log of their teaching activities with the units as well as annotated the margins of the teacher's copy of the units.

Data reported in this study come principally from a thirty item student questionnaire that was administered at the completion of the unit. Ten of the items elicit energy opinion and were used by the National Assessment of Educational Progress. The remaining items were judged by the PEEC staff, the author of this paper, and a panel of twenty teachers to measure their intended purpose. Twelve of the items were designed to ascertain the students' perceptions of the quality of the units, two items to measure the students' attitudes toward school and learning, and six items to determine student goals and to collect demographic information.

Although the details of this formative evaluation project are too numerous to report here, they can be summarized in three broad categories. Generally, students who find school work interesting and find school learning to be relevant to their interests rate most aspects of all three units very highly. Students who indicated a willingness to conserve more energy if they knew how to also rated most aspects of all three units very favorably. Students who possess a realistic view of our energy problems, that is, do not believe our energy problems are over, believe that energy shortages pose a serious threat to the future, and believe that as world consumption of energy increases available supplies to the United States will be less, also feel that the activities in all three units caused them to think a great deal about energy.

## CONCURRENT SESSION H

Session H-1      Research Committee Report: NARST - NSTA  
Cooperative Research Efforts

|            |                                                |                                                       |
|------------|------------------------------------------------|-------------------------------------------------------|
| Presiding: | David Harmon                                   | Claudia Douglass                                      |
|            | Kanawha County Schools<br>Charleston, WV 25311 | Central Michigan University<br>Mt. Pleasant, MI 48858 |

A cooperative research effort of NARST and NSTA has been conducted through the cooperative efforts of these two organizations' research committees. The efforts have included:

- 1) the identification of research priorities for teaching practices as perceived by elementary school teachers of science and secondary school science teachers;
- 2) the development of a research network for science education; and,
- 3) the preparation of a proposal to initiate active participation and cooperation of researchers and teachers in formulating, designing, conducting, and reporting science teaching practice research.

|          |                                             |                                                 |
|----------|---------------------------------------------|-------------------------------------------------|
| Members: | Russell H. Yeany                            | Joan Duea                                       |
|          | University of Georgia<br>Athens, GA 30602   | Price Lab School<br>Cedar Falls, IA 50613       |
|          | Linda R. DeTure                             | Arthur L. White                                 |
|          | 1049 Tuscany Place<br>Winter Park, FL 32789 | The Ohio State University<br>Columbus, OH 43210 |



RESEARCH ON THE ROLE OF THE LABORATORY  
IN SCIENCE TEACHING

Vincent N. Lunetta

The University of Iowa  
Iowa City, IA 52242

Avi Hofstein

The Weizmann Institute of Science  
Rehovot, Israel

Pinchas Tamir

Hebrew University  
Jerusalem, Israel

Ron Raven

SUNY at Buffalo  
Amherst, NY 14260

Herbert J. Walberg

University of Illinois at Chicago Circle  
Chicago, IL 50580

Hayne W. Welch

University of Minnesota  
Minneapolis, MN 55455

James Shymansky

University of Iowa  
Iowa City, IA 52242

John E. Penick

University of Iowa  
Iowa City, IA 52242

### Purpose

- 1) To briefly review the history of the laboratory in science teaching;
- 2) To review research findings regarding the effectiveness of laboratory instruction;
- 3) To critically analyze studies conducted thus far;
- 4) To suggest methods for overcoming the limitations observed in the studies to date;
- 5) To suggest specific new dimensions of potential relevance to teaching and learning in the laboratory;
- 6) To provide a synthesis of suggestions for researchers working to clarify the role of the laboratory in science education.

### Rationale

For years, many science educators have thought the case for science laboratory teaching to be too obvious to need much argument. Laboratory teaching and learning has been assumed by many to have a central and distinctive role in science education. At this time, however, some educators have begun to seriously question the effectiveness and the role of laboratory work and the case for laboratory teaching is not as self-evident as it once seemed. The review of research relating to the science laboratory prepared by Gary Bates and published by NSTA in 1979 provides very little evidence on the basis of which extensive and expensive laboratory teaching can be justified. It is also clear from the review, however, that the research is very incomplete and even inconclusive. If the research community does not provide a critical and positive response, it is reasonable to assume that some educators will cite the Bates report as justification for drastically curtailing laboratory teaching. Past research studies can and should be analyzed and criticized and new dimensions and directions for research on the laboratory should be prepared. Some areas or dimensions of laboratory learning have never been properly explored. The primary goal of this symposium will be to review current research and state of the art and to propose new directions for future research and development on the important topic of laboratory learning in science education.

## A STUDY OF SIXTH-GRADERS' ENERGY ATTITUDES:

### EVALUATION OF AN ENERGY MODULE

Lloyd H. Barrow

University of Maine  
Orono, ME 04469

The purposes of the study were to measure the change in attitudes between the control group, the group that studied energy, and the group that used the energy module, Energy for Today and Tomorrow (Catawba County Schools, 1978), and to compare the differences in attitudes between sexes.

A 17-item instrument modified by Ayers(1976) of the Pennsylvania Department of Education (McDermott, 1973) was utilized to ascertain the attitudes toward electrical energy. The instrument items were grouped into three categories -- nuclear power, environmental impact of electrical power generation, and electrical power generation.

Data was collected from four test sites totaling 163 sixth grade students (83 males and 80 females). Each subject completed the instrument by indicating their degree of agreement or disagreement with each statement on the instrument. Based on student responses the mean score for each statement was computed for each group and sex group. At one site, a random sample of subjects (12 males and 11 females) was selected for a pre/posttest design of the energy module. Both males and females showed a more positive attitude toward electrical energy after completing the module. The gain from pre to posttest was significant according to a t-test at the .05 level. It can be inferred that the energy module did bring about a change in energy attitudes -- although the length of time (three weeks) and the small number of participants indicated further analysis. A two-way ANOVA was done to ascertain the impact of the energy module upon total population. The overall analysis revealed significant treatment level (energy module versus control), sex (male versus female), and interaction (treatment X sex) at .05 level.

Due to significant interaction, the design was partitioned into four separate one way ANOVA which indicated that the significant interaction ( $p \leq .05$ ) was caused by the male control group. The utilization of the energy module provided males with more opportunities for development of positive attitudes toward electrical

energy than for females. The subjects in this study had less positive attitudes toward electrical energy than reported by Ayers. Males within the control group were more cautious than females while the females within the energy module group were more cautious than males.

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## A PRE-CHEMISTRY SECONDARY COURSE ON PROPORTIONAL CALCULATIONS

Madeline P. Goodstein  
William W. Boelke

Central Connecticut State College  
New Britain, CT 06050

The Sci-Math Project undertook the development, teaching, and assessment of a course on the applications of proportional calculations needed by secondary school students to study chemistry and physics. Seventy-six students taking college-preparatory biology studied the sci-math course during their regularly scheduled free periods for a total of half a semester prior to the study of chemistry. Topics covered, not necessarily in order of instruction, were rates, direct and inverse relations, direct and inverse proportions, dimensional analysis, symbolic rate equations set up from data, percentages, interconversions of rate and ratio equations and graphs. Familiar variables from everyday activities rather than from science were used for problems. Several simple laboratory experiments using familiar equipment were performed. A goal of close to 100% achievement was set for the first part of the course. To achieve this took longer than was expected so some of the latter part of the course was not completed.

The effect of the sci-math course on the student's ability to solve problems in proportional calculations not involving scientific concepts was investigated, as was the effect of the course on subsequent performance in chemistry. The data indicate that proportional problem-solving can be successfully taught in the high school when applied to everyday and consumer activities. The null hypothesis that students who had previously studied the sci-math course did not differ in the use of correct strategies to solve chemistry problems from students who had not taken the course was tested by analysis of variance. It was not rejected since the significance was 6%. These results strongly suggest replication of this study. An improved curriculum and a longer period of study may well make the needed difference in chemistry achievement.

Scores on the sci-math course posttest for the control group were significantly related by the chi-square test to Piaget cognitive levels measured by a written test. No correlation between post-test score and Piaget level was found for the experimental group. This suggests that students preparing for chemistry can be taught to solve both concrete and formal proportional calculations independent of the Piaget level of the students when the variables are familiar to the students.



THE EFFECTS OF PROBLEM SOLVING ON THE  
ACHIEVEMENT OF EARTH SCIENCE STUDENTS  
AS MEASURED WITH BLOOM'S TAXONOMY

J. Michael Russell

Averett College  
Danville, VA 24541

Eugene L. Chiappetta

University of Houston  
Houston, TX 77004

Prominent among the goals stated for education is the improvement of students' ability to think. Problem solving is a term that has frequently been used to represent and to promote the notion of thinking. It has been defined for this study as a three-step procedure to include problem identification, inquiry to determine relevant information, and the discovery of relationships. This model of problem solving has many similarities to the application level learning described in Bloom's Taxonomy of Educational Objectives.

The purpose of this study was to improve eighth graders' ability to apply and analyze earth science subject matter through a problem solving approach to instruction.

The population for the study consisted of eighth grade earth science students attending a suburban middle school in the southwest. Fourteen sections ( $n = 287$ ) were randomly assigned to seven control groups.

The control groups received a traditional textbook oriented form of instruction which included reading, discussion, and laboratory activities. The experimental groups received instruction which included reading, discussion emphasizing application and analysis level questions, and problem solving laboratory activities. The treatment lasted six weeks.

A 40-item achievement test was administered to determine the effects of the treatment. It consisted of ten items constructed at the knowledge, comprehension, application, and analysis levels. The test reliability was determined to be .78 (Kuder-Richardson 20).

The Hotelling's  $T^2$  test was used to determine if a pattern of differences was produced across the four subtests between the two treatment groups. This analysis indicated there were significant differences ( $p \leq .001$ ). Univariate F values computed for each subtest showed significance ( $p \leq .001$ ) in each case. A discriminant function analysis determined that the application subtest (.70) appeared to be the best discriminator followed by the knowledge (.34), comprehension (.13), and analysis (.08) subtests.

The median taxonomic level of teacher initiated questions asked during classroom discussion in the treatment groups was analyzed from data recorded on the Teacher-Pupil Question Inventory. The results indicate that the median level of questions asked in the problem solving classes was higher ( $p \leq .005$ ) than in the conventional classes.

The results from this study indicate that the problem solving approach used seems to be an effective means for improving the achievement of earth science students. It will increase test performance at the knowledge, comprehension, application, and analysis levels. In particular this strategy appears to have greatest effect on the application of subject matter.

EFFECT OF A VALUES-ORIENTED ENVIRONMENTAL EDUCATION UNIT ON  
THE ATTITUDES OF PRESERVICE TEACHERS AND ON THEIR STUDENTS

Dorothy M. Andrews

Broomfield School  
Harvard, MA 01451

Gerald Abegg

Boston University  
Boston, MA 02167

The purpose of this research is to evaluate the change in attitude of preservice elementary teachers toward environmental concepts through instruction in a values-oriented environmental education unit and to evaluate the change in attitude toward environmental concepts of pupils taught by these preservice teachers during their student teaching assignments. The null hypotheses are:

- 1) There will be no difference in preservice elementary teachers receiving instruction in a values-oriented environmental education unit and a group of preservice elementary teachers who have not received this instruction.
- 2) There will be no difference in elementary pupils' attitudes toward the environment between a group of pupils taught by teachers who have received instruction in a values-oriented environmental education unit and a group of pupils taught by teachers who have not received this instruction.

The experimental design developed to test both these hypotheses is a Lindquist Type I design. The experiment can be summarized as a pretest/posttest control group design. To measure attitudinal change for the first hypothesis, Environmental Assessment Instrument I was developed. This included a semantic differential consisting of sixteen environmental concepts and a forty-five item cognitive test to measure attitudinal change. For the second hypothesis, Environmental Assessment Instrument II, a Likert-type instrument consisting of ten environmental concepts was developed.

The population for the initial study consisted of 48 undergraduate junior students enrolled in the course, The Learner and His Environment, at Boston University School of Education. Prior to presenting the instruction, Environmental Assessment Instrument I was administered as a pretest. The experimental group received instruction in a values-oriented environmental education unit. At the conclusion of the instruction period Environmental Assessment Instrument I was administered to both groups as a posttest.

Nine preservice teachers and 131 students participated in the follow-up study. Prior to instruction Environmental Assessment Instrument II was administered to all pupils as a pretest. After presenting a mini-environmental unit to their pupils, Environmental Assessment Instrument II was administered as a posttest.

Data from the semantic differential were analyzed by an analysis of covariance which showed there was a significant difference ( $p \leq .05$ ) in attitude toward nine of the sixteen concepts as a result of the values-oriented environmental education unit. An analysis of covariance on the data from the cognitive test showed a significant difference ( $p \leq .0001$ ) in knowledge of ecological facts and principles in the experimental group.

In the follow-up study the posttest scores on Environmental Assessment Instrument II for both the control and experimental groups were analyzed using an analysis of variance. The results were significant beyond the .01 level.

The following conclusions may be drawn from the results of this study:

The attitudes of preservice teachers toward environmental concepts changed significantly as a result of instruction in a values-oriented environmental education unit.

The cognitive knowledge of ecological facts and principles of preservice elementary teachers increased significantly as a result of instruction in a values-oriented environmental education unit.

Preservice elementary teachers who have received instruction in a values-oriented environmental education unit are able to elicit a positive attitude toward the environment in their pupils.

## EVALUATION OF ELEMENTARY SCIENCE MAGNET SCHOOL PROGRAMS

Claude H. Cunningham  
Donna G. Wright

Houston Independent School District  
Houston, TX 77027

The goal of encouraging school integration through instructional means has led many urban public school districts to develop Magnet Schools. Magnet Schools, by definition, are high quality programs which, by the nature of their offerings, attract volunteer students from all racial, ethnic, geographic, and socio-economic sectors of the community. It is assumed that high quality specialized instructional programs will provide adequate motivation and impetus for meaningful voluntary integration.

Any attempt to evaluate Magnet School programs must have at least two dimensions. First, their impact on integration must be determined. Second, the quality of the program must be examined. The evaluation of the quality of the Magnet School Project in Houston assumes that each program will establish objectives which represent a consensus of the profession in both content and academic skills. This assumption requires periodic verification to assure the content validity of Magnet School programs. Results of past validity checks have revealed both strengths and weaknesses which have provided a basis for program revision and revitalization. This paper deals with the design and procedures used in evaluating the elementary science Magnet School programs in Houston. It will serve to introduce the other papers in the set.

### Design

The design selected for this study was a non-equivalent control group design with post hoc analysis. The treatment group was drawn from students attending elementary science Magnet Schools; the control group was drawn from students attending non-science elementary Magnet Schools. The groups are non-equivalent in that randomization was not possible in assigning student groups. Post hoc measurement was necessitated due to lack of opportunity for pretesting.



### Sample

Students were selected from the identified groups for inclusion in the study using random selection of student identification numbers by computer. Members of both groups were attending Magnet Schools during the study and had been enrolled in the same Magnet Schools for at least one and one-half years prior to the study. Students in the study samples were randomly selected from groups which were alike in ethnic make-up and sex distribution. This balance is controlled by a federal court desegregation order.

### Instrumentation

Four variables were identified for measurement and analysis in this study. The variables were: science content achievement, skill in classifying and inferring, and general academic achievement. Science content achievement was measured using the Science subtest of the SRA Achievement Series. General academic achievement was measured using the Composite Score of the Iowa Test of Basic Skills...

Students' skills in classifying and inferring were measured using two locally produced tests; the Whitson Classifying Measure and the Whitson Inferring Measure. The development of these tests is discussed in another paper in this set.

### Procedures;

Students selected to participate in this study were tested in the Magnet School they attended in groups of 30 or fewer. The four instruments were administered at three sessions with about two weeks between sessions.

THE DEVELOPMENT OF NON-READING, PAPER AND PENCIL  
MEASURES OF CLASSIFYING AND INFERRING SKILLS

Betty A. Whitson

Houston Independent School District  
Houston, TX 77027

Jacob W. Blankenship

University of Houston  
Houston, TX 77004

Introduction

Validated, non-reading, paper and pencil, group administered assessment instruments designed to accurately assess student abilities to classify and infer were essential to the research design of this study. A search of the literature on assessment instruments to identify such measures appropriate for use with fifth and sixth grade students was unsuccessful. The task of designing, developing, and validating instruments that met the design criteria are described in the presentation.

The Whitson Classifying Measure

The Whitson Classifying Measure is an assessment instrument designed to measure the abilities of children to classify. Selection procedures of the classifying items were implemented in three phases:

- 1) Efforts were first directed towards careful review of the literature to locate a validated instrument which could be administered to a group of twenty-five or more which involved no reading. Only one instrument appeared to meet the criteria; however, attempts to secure the test were unsuccessful (Nowak's Classifying Measure);
- 2) Adaptation of existing curriculum materials and research findings resulted in the development of an assessment measure, The Whitson Classifying Measure;

- 3) A validation study was undertaken using a sample of 48 students. Mean item discrimination for the assessment measure ranged from 0.40 to 0.58. The Kuder-Richardson 21 Reliability was 0.86 for the instrument.

#### The Whitson Inferring Measure

The Whitson Inferring Measure is an assessment instrument designed to measure the abilities of children to infer. A search of the assessment literature revealed only two instruments, the Miller Analogies Test and an instrument developed by the American Association for the Advancement of Science for Science -- A Process Approach, neither of which was adequate for the study. Subsequently, the Whitson Inferring Measure was developed by adapting existing curriculum material and research findings. A validation study was done using 48 students. Mean item discrimination for the assessment instrument ranged from 0.45 to 0.60. The Kuder-Richardson 21 Reliability was 0.88.

A STUDY OF THE DIFFERENCES BETWEEN SCIENCE MAGNET  
SCHOOL STUDENTS AND NONSCIENCE MAGNET SCHOOL  
STUDENTS ON MEASURES OF SCIENCE SKILLS AND ACHIEVEMENT

Jacob W. Blankenship

University of Houston  
Houston, TX 77004

Betty A. Whitson  
Claude H. Cunningham

Houston Independent School District  
Houston, TX 77027

Introduction

The evaluation of the elementary science Magnet Schools in an urban school district was made by the comparison of students' abilities to classify and infer and the students' general academic achievement.

Sample

Two hundred and eleven students from fifth and sixth grades in five elementary schools participated in the study. The schools were chosen from various areas of a large urban school system. Half the sample were from schools where science was the focus of the magnet school program and the other half of the sample were from magnet schools that had a curriculum focus other than science.

Procedure

Students were tested in groups of 30 or fewer using four assessment measures, two for measuring science skills and two for measuring academic achievement. The independent variables of the study were type of school attended (science magnet or nonscience magnet) and the dependent variables were the skills of classifying and inferring and general academic achievement in reading, mathematics, and science content. The t-test was used to determine significant difference.

RELATIONSHIP OF ELEMENTARY STUDENTS' CLASSIFYING AND  
INFERRING SKILLS TO MEASURED ACHIEVEMENT IN BASIC SKILLS

Donna G. Wright  
Claude H. Cunningham

Houston Independent School District  
Houston, TX 77027

Jacob W. Blankenship

University of Houston  
Houston, TX 77004

Introduction

The "back to basics" movement in public education has had two negative effects on elementary science education. The movement has defined "basic skills" as reading and mathematics. Science has been de-emphasized in favor of increased instructional time in reading and mathematics instruction. Second, the movement is more congruent to a content acquisition emphasis than a processing skills development emphasis in elementary science. Empirical evidence is needed to describe the relationship of the information processing skills to basic academic skills. Such evidence holds promise for a broadening of the definition of basic skills as well as providing science education with adequate emphasis for survival.

Sample

Data related to student classifying and inferring skills and general academic and science achievement were collected. A total of 186 students' scores were obtained. Students were randomly selected from groups which were alike in both ethnic make-up and sex distribution. All members of the identified groups had been continuously enrolled in Magnet Schools for at least one and one-half years.

Instrumentation

Four variables were identified: science achievement, information processing skill development in classifying and inferring, and general academic achievement. Science achievement was measured



### Findings

The students who attended the science magnet schools outperformed the nonscience magnet school students on each of the five dependent variables. The differences were statistically significant.

using the Science subtest of the SRA Achievement Series, Level E/Form 1. General academic achievement was measured using subscale scores of the Iowa Test of Basic Skills Level 11-12/Form 5. Students' information processing skill development in classifying and inferring was measured using the Whitson Classifying Measure and the Whitson Inferring Measure. The development of these instruments has been described in another paper in this set.

### Results

The rationale for selecting specific information processing skills was their assumed relationship to general academic achievement. To determine the validity of this assumption, student scores on each of the two information processing skills measures, inferring and classifying, were correlated with each of eleven academic achievement areas measured by the Iowa Test of Basic Skills and the Science score on the SRA Achievement Test.

Each of the information processing skills was significantly correlated with each of the academic areas. This pattern of correlations indicates that inferring and classifying have relationships to general academic achievement. Two achievement areas have correlations with inferring which exceed 0.4; Reading Vocabulary ( $r = 0.44$ ) and Reading Comprehension ( $r = 0.41$ ). Four achievement areas have correlations with classifying which exceed 0.4; Mathematics Concepts ( $r = 0.53$ ), Knowledge of References ( $r = 0.48$ ), Mathematics Problem Solving ( $r = 0.45$ ), and Graph Reading ( $r = 0.44$ ).

### Discussion

From this analysis, several conclusions may be forwarded. First, students' information processing skill development in inferring and classifying is significantly positively related to general academic achievement. Those students who score higher on measures of information processing skill development also score higher on measures of general academic achievement. Achievement in science content is not significantly related to either information processing skill development or general academic achievement. While we cannot infer causation based on this study, we are comfortable encouraging instruction specifically designed to improve students' information processing skills.

IMPLICATIONS AND RECOMMENDATIONS ARISING OUT OF AN EVALUATION OF  
ELEMENTARY SCIENCE MAGNET SCHOOLS IN A MAJOR URBAN SCHOOL DISTRICT

Claude H. Cunningham

Houston Independent School District  
Houston, TX 77027

Jacob W. Blankenship

University of Houston  
Houston, TX 77004

Magnet Schools have become the major vehicle for encouraging school integration through instructional means. This paper discusses the implications and recommendations arising out of a broad based research study designed to evaluate the effectiveness of elementary science Magnet Schools in a major urban public school district. Basically, the design provided for the comparison of certain skills and achievement between students attending science and nonscience Magnet Schools. Analyses of correlation and difference were employed in the study. The major components of the study are reported in preceding papers in this set.

Findings

The findings of this major evaluation study may be summarized in the following statements:

- 1) Effective, non-reading, paper and pencil measures of elementary students' classifying and inferring skills can be developed;
- 2) Significant correlations exist between students' classifying and inferring skills and their scores on standardized general achievement measures;
- 3) No significant correlations exist between students' classifying and inferring skills and their scores on standardized science achievement measures;
- 4) Science Magnet School students perform significantly better on measures of classifying skill, inferring skill, and general achievement than their nonscience Magnet School peers;

- 5) Science and nonscience Magnet School students' performances on measures of science achievement are not significantly different.

#### Implications and Recommendations

Several implications and associated recommendations present themselves from the findings summarized above. Students' classifying and inferring skills are significantly positively related to general achievement and, therefore, development of these skills should be emphasized. Since students' programs emphasizing daily hands-on activities using physical objects perform significantly better on measures of classifying and inferring skill and general achievement, a method for enhancing student development in these areas evidences itself. We recommend that activities involving the manipulation of physical objects be infused into the curriculum throughout the elementary grades.

Students in the two types of Magnet Schools did not perform differently on measures of science content achievement. This presents a paradox to the science educator. On one hand, the public sees standardized test performance as one of the few real indicators of excellence. On the other hand, this finding, when coupled with findings of significant difference in process skill development and general achievement, appears to be a positive result when compared to the emphasis expressed in the professional literature. Since there is no indication that a science content emphasis in Magnet Schools results in significant differences in science achievement between science and nonscience Magnet School students, it is again apparent that the results obtained here argue for a physical objects oriented curriculum. While the lack of difference in science achievement scores may be unsettling, mitigating factors related more to the measure used than the program must be considered. On this finding, we recommend replication of the study for verification.

This study did not result in data which would allow inferences of causation to be drawn. It does, however, indicate at least two clear directions for educators in the "back to basics" era. First, hands-on activities are of critical importance in the development of basic academic and cognitive skills. Second, a program which consistently emphasizes the development of process skills produces students who are superior on most measures to their peers in other programs.

CONCURRENT SESSIONS I AND J

Sessions I-2 and J-2    Techniques and Procedures of Research

Topic:                      The Design and Implementation of an  
Evaluation Plan

Arthur L. White

The Ohio State University  
Columbus, Ohio 43210

This session has been designed to provide the participants with procedures, materials and skills which will facilitate the design and implementation of an evaluation plan. The session will be conducted with application as the major focus. Activities and handouts will be included during the session.



DEVELOPMENT AND VALIDATION OF PROCEDURES TO ANALYZE  
MULTIPLE CHOICE ITEMS: AN APPROACH TO ASSESSING KNOWLEDGE

John A. Caldwell

University of North Dakota  
Grand Forks, ND 58202

A question raised by educational researchers studying the cognitive organization of knowledge before and after instruction is "How does the knowledge a person has previously acquired interact with organized instructional content to produce a new knowledge structure in the person's mind?" (Posner, et al. 1977). To answer the question of knowledge interaction requires assessment. The assessment of an individual's knowledge and its organization presents a difficult methodological problem.

Traditional assessment procedures position an individual on a continuum and compare individuals with each other (Magnusson, 1967). Although traditional assessment items test knowledge of propositions (Ebel, 1965) the scores received from the analysis indicate a proportion of acquired knowledge rather than specific acquired knowledge.

This study focuses on one kind of knowledge to be acquired -- propositional knowledge. The purpose of the study was to develop and apply techniques for the analysis of student knowledge as demonstrated by the propositions the student implicitly asserts on multiple choice items.

The study was conducted during the summer of 1978 at Michigan State University. Twenty-seven elementary education majors enrolled in Biological Science 202 provided the sample for the study.

Student responses to an essay question and a set of multiple choice questions developed for a unit on terrestrial succession were analyzed.

The analysis involved the following steps:

- 1) analyze the multiple choice test and derive the inherent propositions;

- 2) organize the propositions and apply the student responses to that organization;
- 3) following Pines (1977), derive propositions from the essay responses and calculate the inter- and intra-judge reliability of the essay analysis;
- 4) calculate the percentage agreement between the students essay propositions to estimate the validity of obtained information.

The developed techniques generate a list of propositions implicitly asserted by the students. The organization of the propositions provide a model of student knowledge. The calculated reliability coefficients and percentage agreement indicate the information obtained by the techniques is reliable and valid.

The techniques developed in this study provide a method that can use multiple choice items to assess the propositional knowledge of students. Researchers concerned with the organization of propositional knowledge can capitalize on another data source for the assessment of propositional knowledge, and further their investigation of how one organizes knowledge. Further research could provide a computer program of the techniques so the method could be combined with regular test analysis procedures. This would benefit those instructors who desire to address student misunderstandings.

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ASSESSING PROPOSITIONAL KNOWLEDGE: CHILDREN'S  
CONCEPTIONS OF THE OXYGEN-CARBON DIOXIDE CYCLE

Edward L. Smith

Michigan State University  
East Lansing, MI 48824

Rationale and Objectives

Curriculum evaluation and research on science teaching frequently require careful assessment of what students know and learn. Scores on norm or domain referenced tests reflect the amount known, but not what specific knowledge the individuals do and do not possess or what alternative conceptions the individuals have. The purpose of the research was to develop methods for assessing and modeling students knowledge of a given topic.

The work was guided by a cognitive view of knowledge and its relation to performance. Thus an individual's knowledge was viewed as consisting of integrated sets of propositions and procedures. Observed task performance was viewed as resulting from an application of an individual's knowledge, and thus as providing a basis for inferences about the underlying knowledge.

The specific objectives were to:

- 1) develop methods for assessing and modeling students' propositional knowledge of a given topic;
- 2) apply those methods to the assessment of student knowledge related to part three of the SCIS Ecosystems unit "The Oxygen-Carbon Dioxide Cycle"; and,
- 3) assess the utility of the methods for use in research and evaluation.

Method

The Ecosystems Teachers Guide was analyzed to identify the propositional knowledge addressed in Part 3. Three instruments were then constructed for assessing these propositions:

- 1) a multiple choice test which tested primarily recall or low level generalization of propositions;

- 2) a written test which required application of propositions to new problems (presented in writing and drawings) similar to those dealt with in the instruction; and,
- 3) an inquiry practical test which required application of propositions in the course of first hand investigation of new phenomena.

After piloting and revision, the tests were used to assess knowledge and learning of two classes of sixth grade students ( $n = 17, 15$ ) studying the SCIS Ecosystems Unit. The multiple choice test was administered as both a pre and posttest. The written and inquiry practical tests were administered as posttests only.

Answers to each test were analyzed to produce lists of propositions attributed to each student. Visual inspection of conceptual network representations and computer analysis including cross tabulation, cluster analysis and path analysis were used to identify alternative conceptions held by students and examine the relationships among the results from the three tests.

#### Instruments and Data

The multiple choice test consisted of 24 items with three to five alternatives including "I don't know." Alternatives were designed to be sensitive to anticipated alternative conceptions.

The written test presented, in writing and pictorially, five different situations about which the students were to predict, explain and/or model diagrammatically. Thirty-six separate responses were required.

The inquiry practical presented two novel phenomena and a series of written questions which required the students to observe, hypothesize, design experiments, predict results, perform experiments, and interpret results.

The student responses to all tests were transformed into lists of propositions, the supporting evidence for each being carefully documented. These lists were the data for all further analysis.

#### Results

The study identified conceptions commonly held prior to instruction and conceptions, both valid and invalid, which developed during instruction. The multiple choice test elicited more complete data but some students interpreted item options differently than intended. Adequate ( $\neq 80\%$ ) inter-judge agreement was obtained in analyzing written responses and adequate agreement across tests (cross validity) was obtained although some systematic differences were identified.

### Conclusions

The methods are very promising for use in research and evaluation. However, use of the full propositional analysis of written responses will probably not be practical for regular classroom application.



THE RELATIONSHIP BETWEEN ATTITUDES TOWARD SCIENCE AND SCIENCE  
ACHIEVEMENT THROUGH THE USE OF RESIDUALIZED SCORES

Linda W. Hough

Houston Community College  
Houston, TX 77007

Martha K. Piper

University of Houston  
Houston, TX 77004

The relationship between attitudes toward science and science achievement has been proposed and investigated by many studies (Brown, 1955; Hedley, 1966; Littlefield, 1975). The results of these studies indicate that how well a student likes science is related to how well he/she does in science. Alvord (1972) stated that this relationship varies according to certain individual pupil characteristics such as sex, race, and grade level. One method of controlling for these individual differences is through the use of residualized scores. Kerlinger (1973) states that the best technique for analyzing change in a pretest-posttest situation is through the use of residualized scores. These scores are the posttest scores with the influence of the pretest scores removed from them. This study investigated the relationship between elementary pupils' attitudes toward science and their science achievement. Residualized scores were used to analyze the data.

Each teacher was given an identical science lesson plan that included all the materials needed for the activity. Detailed instructions for administering the pre and posttest to the elementary pupils were also included. The subjects of the study were 583 intermediate elementary pupils enrolled in the Houston area school districts in the Spring 1978 semester.

The following instruments were given to each of the subjects:

- 1) Hough Attitude Test
- 2) Hough Pupil Process Test

Each of these instruments were developed by the researchers to directly relate to the science lesson.

The pupils in each of the teacher's classrooms were pre and post-tested as part of the science lesson. Residualized scores were used to correct for any pretest differences that may have existed. To calculate residualized scores, the posttest scores are modified by removing any variance that can be attributed to the pretest. Therefore, all pretest influences are removed.

A zero order correlation was used to test the hypothesized relationship. The significant level of criterion was established at five percent of probability.

The analysis revealed that there was a significant relationship between the pupil's residualized scores on the Hough Pupil Process Test and their residualized scores on the Hough Attitude Inventory ( $r = .45$ ).

Residualized scores are more appropriate than change scores because they are the result of statistically controlling for individual differences among pupils. Since this study statistically controlled for individual differences among pupils on the affective and cognitive tests, a stronger case can be made for the relationship found between attitudes toward science and science achievement.

The importance of this study is the implication that teachers teaching science can provide the conditions that promote the relationship between positive attitudes toward science and science achievement.

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## A CONTENT VALIDATION OF THE PIAGETIAN LOGICAL OPERATIONS TEST

John R. Staver

DePaul University  
Chicago, IL 60614

The investigator's purpose in this investigation was to determine the content validity of the Piagetian Logical Operations Test, PLOT, (Staver, 1978; Staver and Gabel, 1978). The evidence gathered from experts should prove valuable in further development and revision of PLOT.

The Piagetian Logical Operations Test is an objective multiple choice instrument which can be administered to classroom sized groups. The test is patterned after a series of Piagetian interviews and contains questions, in multiple choice format, which assess the content of tasks, plus the decisions and reasons employed by students in solving problems. Tasks are demonstrated on video tape.

Three university faculty members with background in science, science education, Piagetian psychology, and Piagetian group instrument development were invited to critically review PLOT. Each evaluator was given a packet which included a cassette video tape of PLOT task demonstrations, a PLOT test booklet, directions for administration, answer key, and an evaluation form. All evaluators completed and returned the forms to the investigator.

The evaluation form consisted of thirteen statements, and each person responded "agree", "undecided", or "disagree" to each assertion. The sentences were concerned with:

- 1) the association between the presence of mental schema in subjects and their scores on individual PLOT scales and the total test;
- 2) the similarity between the logic required to score well on individual PLOT scales and the total test, and the corresponding Piagetian clinical tasks; and,

- 3) the appropriateness, efficiency, and practicality of the PLOT format compared to the clinical method in the measurement of Piagetian mental schema.

The evaluators were also requested to write their thoughts, comments, and suggestions in the space provided on the evaluation form.

There was unanimous or majority agreement on three issues:

- 1) individuals possessing considerable conservation of volume, combinatorial analysis, direct and inverse proportion, and general formal thought skills will score higher on PLOT than persons not possessing such skills;
- 2) the logic necessary to score high on PLOT parts I, IV, and PLOT total is similar to the logic required to solve the corresponding clinical tasks; and,
- 3) PLOT is more practical when large numbers of subjects are tested.

A majority were undecided in two areas:

- 1) persons who possess considerable separation and control of variable skills will score higher on PLOT than individuals not possessing such skills; and,
- 2) the PLOT format is more efficient and appropriate than the clinical method.

A majority disagreed that the logic required to score high on PLOT part II is similar to the logic of the corresponding clinical task.

Discussion is focused upon the experts' comments and responses with respect to construct validity evidence (Staver, 1978; Staver and Gabel, 1978) and the responses and comments themselves. Recommendations for further development, inquiry, and classroom use of PLOT are made.

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THE DEVELOPMENT AND VALIDATION OF AN INSTRUMENT FOR  
MEASURING MEDICAL ETHICS VALUES

Cynthia J. Stolman  
Rodney L. Doran

State University of New York  
Buffalo, NY 14260

The present decade has brought a steady increase in the teaching of medical ethics both in medical schools and in universities. The relative infancy of medical ethics teaching may explain the current lack of any tools to evaluate these new teaching efforts. Most medical schools in the United States rely heavily upon objective measures for choosing future students. "The Association of American Medical Colleges has for several years been engaged in trying to define and reliably measure noncognitive factors in developing a system for use in student selection." (Schorow, 1976) The Hastings Center (Institute of Society, Ethics and The Life Sciences) has listed evaluation of ethical decision making as one of their major goals. There would appear to be a genuine need for the development of an objective, valid tool to evaluate medical ethics decision making. The present study was concerned with the construction and validation of a Medical Ethics Inventory (MEI), which will provide profiles of the value preferences of medical students regarding medical-ethical dilemmas.

The MEI was constructed using the six value categories of Eduard Spranger (1928) (Aesthetic, economic, political, religious, social, and theoretical) as a philosophical basis. Several test instruments have been developed with Spranger's six value types as the theoretical basis. The Allport, Vernon and Lindsey Study of Values (SOV) (1970) is the best known. It is a general test of attitudes and values and provides a general profile. It might be regarded as somewhat dated, and may not be relevant for measuring specific values, such as medical ethics. The MEI uses a case study approach, presenting actual medical dilemmas. "Much of medical ethics, especially within the profession itself, is indeed oriented to the practical questions of what should be done in a particular case. Medicine, even more than business and law, is case oriented." (Veatch, 1977) The cases were chosen from four major themes:

- 1) Respect for life;
- 2) Equality (Distributive Justice);
- 3) Covenant Relationships; and,
- 4) Individual Freedom

(Gorovitz, 1976; Bandman and Bandman, 1978; Keller, 1977).

The formation of the instrument followed these steps:

- 1) An open format was used with 135 university students who were taking a course in medical ethics;
- 2) Judges were used to match responses with definitions that represent the value domains;
- 3) The value profile of "known types" (six judges) was determined to be consistent with the constructs;
- 4) Problems that did not conform to certain criteria were eliminated; and,
- 5) The wording supplied by respondents was used in composing choices because it was closer to reality.

The present study is an empirical validation of the MEI. Two hypotheses were tested:

- 1) Is there a relationship between values in a medical ethics context and "known groups"?
- 2) Is there a relationship between general values and medical ethics values?

For the first hypothesis, approximately 50 subjects were chosen from each of the following groups.

- |                |                                          |
|----------------|------------------------------------------|
| 1) Aesthetic   | Art students                             |
| 2) Economic    | Commerce students                        |
| 3) Political   | First year law students                  |
| 4) Social      | First year social work students          |
| 5) Religious   | Second year seminary students            |
| 6) Theoretical | First year chemical engineering students |

The first hypothesis was analyzed using a one way multivariate analysis of variance model (Finn, 1974). Approximately 150 first year medical students from four different medical schools participated in the second phase of the study. The second hypothesis was analyzed using a Cooley-Lohnes (1971) routine called CANON.

Results from testing the first hypothesis were examined to ascertain if known groups did exhibit preferences consistent with their major vocational interest i.e. seminary-religious. Results from testing the second hypothesis consisted of a canonical correlation coefficient used to detect any commonality between the general (SOV) and the specific (MEI) value assessments. The two canonical factor patterns obtained were examined for similarity.

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A PATH ANALYTIC APPROACH TO THE IDENTIFICATION OF CAUSAL  
RELATIONSHIPS EFFECTING POST OBJECTIVE TEST PERFORMANCE

Michael Duffy

University of Pittsburgh  
Pittsburgh, PA 15243

Johnson (1967), Shavelson (1973), and Duffy and Bond (1978) have demonstrated the utility of measures of cognitive structure for specific science concepts. Other research has related pretest-posttest performance to indices of mental ability. A model relating these variables to a pretest-instruction-posttest paradigm could be useful in identifying causal factors influencing posttest improvement.

Path analysis, as outlined by Wright (1921), provides a method for studying the relationships between variables taken as causes and variables taken as effects. The present study is an attempt to demonstrate causal relationships (mental ability and cognitive structure) through a path network effecting posttest performance.

Methodology and Design

Fifty suburban junior high earth space science students (23 male, 27 female; mean age 13.2, s.d. 0.58) were used in the experimental design involving a three part unit in elementary geology.

| <u>Day</u> | <u>Treatment</u>                                                                                                                                 |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| 1          | Verbal and figural abstract reasoning assessment.                                                                                                |
| 2          | Prose recall to the stimulus "write what you know about rocks" (prose recall) Card sorting activity (presort). Geology objective test (pretest). |
| 3          | Instruction unit A in elementary geology. Card sort activity (midsort).                                                                          |
| 4          | Instruction unit B in elementary geology. Prose recall (midprose).                                                                               |
| 5          | Instruction unit C in elementary geology.                                                                                                        |
| 6          | Prose recall (postprose). Card sort activity (postsort). Objective test (posttest).                                                              |
| 36         | Delayed prose recall (delayed prose). Delayed card sort activity (delayed sort).                                                                 |

### Instruments

Thirteen terms (rock, igneous, sedimentary, metamorphic, limestone, sediment, granite, pumice, magma, marble, shale, slate, and lava) identified as representative of the three instructional units were used in the card sorting activity and prose recall analysis. The card sort utilized each geology term on 13 separate cards. The subjects arranged the cards in a pattern that "made sense" to them. A quantitative index reflecting the response card sort departure from the correct card sort arrangement was calculated using the formula:

$$L_i = \text{Log} \sum_{j=1}^n \left( \sum_{k=1}^n i d_{jk} \right) \left( \sum_{k=1}^n i d_{kj} \right)$$

where  $i d_{jk}$  is the  $jk$ th element of matrix  $D = R_i - R$  for student  $i$ .

Matrix  $R$  ( $R_i$  for student  $i$ ) is the  $R = C + C^2$   $n \times n$  matrix when  $C$  is the adjacency matrix of the elements of the card sort (Duffy and Bond, 1978).

The prose recall was evaluated as to the frequency and variety usage of the same thirteen geology terms. Objective test performance was measured simply as the number correct on a four part 33 item standard geology test.

Indices of verbal abstract reasoning ability were derived from the 20 item Shipley (1946) test. Figural mental ability was determined by means of a group administered battery of 18 Piagetian type tasks (Moser, 1975).

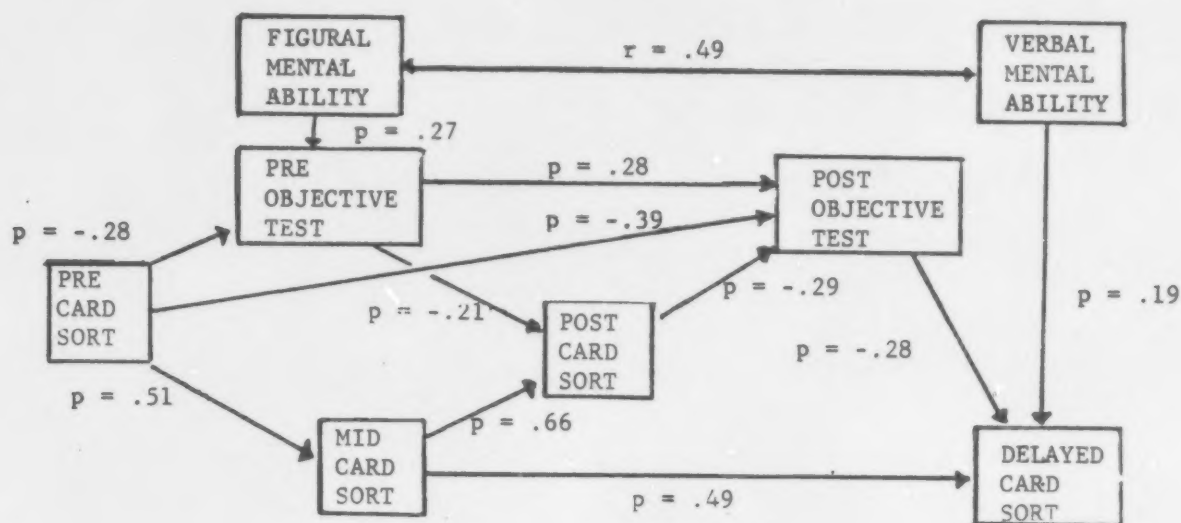
Statistical analysis utilized the BMDP2R stepwise regression and BMDP8D correlation programs from the UCLA Health Sciences Computing Facility (Dixon, 1975).

### Findings and Conclusions

Five stepwise regression models were developed ( $F$  to enter = 3.0, tolerance = 0.01) using the delayed sort, posttest, post-sort, midsort, and presort as the dependent variables (all significant at the .05 level or better). The figural and verbal indices were treated as exogenous due to the lack of significant correlation with mental ability variables. All other variables are treated as endogenous to the system.

The following figure shows the path network as identified by the standardized beta coefficients from the regression equations. This system is consistent with the assumptions that underlie the application of the path analysis technique (1-relationship among variables linear, additive, and logically causal; 2-residuals not correlated with preceding variables or other residuals; 3-a recursive system).





Path system identified by the five regression equations where  $p$  = path coefficient = standard beta coefficient.

The original correlation matrix between all variables and the reproduced correlations calculated from the path network show a reasonable approximation, indicating the viability of the path model.

The original treatment of the prose recall data has not been incorporated into the path network at this time. While there exists significant zero order correlations between term usage and card sorting, test performance, and mental ability, significant entry into the path model occurs only between postsort and postprose (partial  $r = -.31$ ) and delayed sort and preprose (partial  $r = -.31$ ).

This path model shows that a traditional measure of classroom achievement, an objective test, is more closely related to the student's prior cognitive structure as measured by the card sorting activity than either a preinstruction objective test or indices of mental ability. This relationship can be quantified as to the direct effect of the prior structure ( $p = -.39$ ) and the indirect effects of this prior structure transmitted through the pretest ( $p = -.08$ ) and through the changing cognitive structures of the mid and postcard sorts ( $p = -.10$ ).

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DEVELOPMENT A DECISION-MAKING MODEL FOR DESIGNING A  
METHODS COURSE FOR PROSPECTIVE SECONDARY  
SCIENCE TEACHERS: A DELPHI STUDY

Frank E. Crawley

University of Texas  
Austin, TX 78712

Maria Virginia dos Santos Silva

University of Azores  
Portugal

The purpose of this paper is to present the results of a study of the objectives of secondary science methods courses and the concerns of instructors when planning methods courses. Specifically the study was designed:

- 1) to seek the opinions of university professors of science education to obtain and compare priorities and areas of concern in planning a science methods course for secondary school teachers;
- 2) to determine the degree of importance and consensus existing among those experts regarding the different objectives and concerns which they have identified; and,
- 3) to discover the concerns of those educators were related to the judgment of the importance of the objectives.

To accomplish this study, a Delphi technique was employed to obtain and compare the opinions of twenty-four university professors of science education. A list of fifteen objectives, and five areas of concern was compiled. Consensus was obtained for all fifteen objectives, although at different levels of importance. Concerns were ranked according to their order of importance. Teacher concerns received the highest percentage of responses. A relationship between planning concerns and objectives was established.

It was found that only three objectives occupied the same rank order for the three major groups expressing different concerns. First in order of importance was objective five (plan one or more science lessons). In second place was objective nine (construct a classroom evaluation scheme). The unanimous choice for eighth place, and the last in order of importance, was objective seven (design remedial activities for students who lack prerequisite skills for a given set of objectives). The remaining objectives did not follow a predictable pattern among the groups.

Based on the research findings of this study, the researchers proposed a model for planning a secondary science methods course. In addition, guidelines for using the model were presented; their use would allow secondary science methods instructors to plan a methods course which reflects their concern while at the same time stressing objectives validated by a national panel of experts.

THE USE OF HOVLAND'S PERSUASIVE COMMUNICATION FRAMEWORK TO  
CHANGE ATTITUDES OF PRESERVICE ELEMENTARY TEACHERS  
TOWARD SCIENCE

Barbara L. Grabowski

University of Maryland  
College Park, MD 20742

Robert L. Shrigley  
Paul W. Welliver

Pennsylvania State University  
University Park, PA 16802

Objectives and Rationale

The primary objective of this investigation was to determine if Shrigley's theoretical example in science developed from Hovland's persuasive communication framework was effective in changing the attitudes of preservice teachers toward the teaching of science. The secondary objective was to determine what effect the individual difference variable of integrative complexity has on the degree of attitude change when subjects were presented with a persuasive communication which matched their level of abstractness/concreteness.

Since elementary teachers reportedly have a less positive attitude toward science, Shrigley identified the important elements to be included in a persuasive communication to change that attitude by using Hovland's framework, "who says what to whom with what effect?" (Hovland, 1953). Investigating the 'who' Shrigley (1976) polled elementary education majors to identify the characteristics of a science communicator who would be perceived as credible. Polling science educators across the country, Shrigley (1978) identified six major ideas to be included in the 'what'. The 'whom' component was assumed to be "those preparing to teach science in the elementary school" (Shrigley, 1978, p. 335). To measure the 'what effect' he designed a science attitude scale. This proposed content was theoretical and had not been tested empirically.

Due to the importance of noting individual difference variables in information processing, integrative complexity which determines the subject's ability to transfer the cognitive information presented at the moment to existing knowledge or attitudes



was considered as a further description of the 'whom' component. In this case, transfer should occur between the cognitive information from Shrigley's identified components to the subject's attitude toward science.

#### Methodology and Design

Ninety-three undergraduate volunteers from a media methods class participated in this study. They were block-randomized by level of integrative complexity to one of three groups. Two groups listened to a persuasive communication and the third was the control. The first persuasive communication contained all the essential elements identified by Shrigley. The second contained all of these elements plus a discussion of the relationship between this cognitive information and the subject's attitude toward science.

With a pretest, posttest, control group design, analysis of variance with repeated measures was calculated to determine if any significant change in attitude resulted from listening to either persuasive communication, and to investigate the difference between the groups when integrative complexity was added to the model.

#### Instruments and Data

Data was gathered for the pre and posttest by administering the Shrigley Attitude Scale for Preservice Teachers. The Conceptual Systems Test was administered to determine the subject's level of integrative complexity.

#### Results and Conclusions

A significant gain in positive attitudes was noted for subjects who listened to either persuasive communication but not for the control group. No significant difference between cells resulted for the individual difference variable of integrative complexity. As a result, this investigation has shown Shrigley's theoretical example in science developed from Hovland's persuasive communication framework to be effective in changing attitudes of preservice teachers toward science.

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THE EFFECTS OF PROCESS SKILLS INSTRUCTION AND INFORMATION  
ON FAMOUS BLACK SCIENTISTS ON THE CLOSED-MINDEDNESS OF  
PRESERVICE TEACHERS

Richard L. Campbell  
Ralph Hogges  
Dennis Murphy

Florida International University  
Miami, FL 33199

Psychologists and educators have shown a great deal of interest in personality traits and attitude changes during the last two decades as a means of understanding human behavior. It has been hypothesized that attitude changes are affected by a person's belief system (Rokeach, 1960). Open-minded persons are usually described as being more willing to change and adapt to new and innovative ideas, whereas the close-minded person has been described as one exhibiting attitudes which are just the opposite. Belief systems and attitude changes are important to the science educator, since a great deal of emphasis on teacher training at the elementary school level is placed on having teachers teach their pupils science process skills. The purpose of this study was to test the contention that science process skills instruction and information on black scientists can alter the belief systems of closed-minded individuals.

Preservice teachers enrolled in competency-based science methods courses at Florida International University were the subjects in this study. The design was the Campbell and Stanley (1963) Pretest-Posttest Control Group Design. Subjects were assigned to two groups based on their median Rokeach Dogmatism Score, which also served as a pretest. Subjects scoring above the median score were considered closed-minded and those scoring below the median were considered open-minded. The groups constituted two experimental groups and each group consisted of both open and closed-minded subjects. One of the experimental groups was randomly assigned instruction in science process skills, plus information on black scientists, while the other group received instruction in science process skills plus information on various books for elementary children. Upon completion of the experimental instructions, the Rokeach Dogmatism Scale was again administered as a posttest.

An analysis of covariance was used to determine if significant changes occurred between the close-minded subjects after the experimental instructions were completed. The data analysis revealed a significant change in the dogmatism of closed-minded individuals ( $p \leq .001$ ,  $F = 30.25$ ,  $df_1=43$ ), with positive difference favoring the group receiving instruction in process skills plus information on famous black scientists. From these results it can be concluded that process skills and information on famous black scientists can be effectively used as a mechanism to change the attitudes of individuals considered closed-minded.

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TEACHING PREADOLESCENTS TO ACT AS SCIENTISTS:

A REPLICATION AND EXTENSION

OF AN EARLIER STUDY

J. Dudley Herron  
Thomas Greenbowe  
Carolyn Lucas

Purdue University  
West Lafayette, IN 47907

John Staver

DePaul University  
Chicago, IL 60614

Charles Ward

Colorado State University  
Ft. Collins, CO 80521

Susan Nurrenbern

University of Missouri  
Kansas City, MO 64108

A number of research efforts have been directed toward accelerating the acquisition of formal operational logic. Teaching the scheme of control of variables formed the basis for a series of studies by Lawson and Wollman (1976), Bredderman((1973), Linn, Chen, and Thier (1977), and Howe and Mierzwa (1977). The only study from this group which reported a significant training effect was the one by Howe and Mierzwa.

Standing in sharp contrast to the studies just reported is one by Siegler, Liebert, and Liebert (1973). These authors claim to have taught the control of variables concept to 11 year-olds in a single 20 minute training session.

While the Siegler, et al. results are interesting, there are alternative interpretations of their data. Specifically, we object to the following statements as unsubstantiated by the experiment, and seriously misleading in their implication.



Given instructional guidance of several kinds, the 10 and 11 year olds were able to exercise formal operations logic and to produce solutions closely resembling those cited by Inhelder and Piaget as exemplifying the highest stage of reasoning. (p. 100)

However, Inhelder and Piaget's proposed explanation in terms of cognitive unreadiness appears inadequate; given appropriate instruction, preadolescent individuals clearly are capable of separating the effects of weight and length and of determining which of the two affects a string's rate of movement. (p. 101)

We have no doubt that the authors were able to get preadolescents to identify length as the variable that affects the period of a pendulum. We do not believe that they have used formal operations to do so or that there is evidence from the Siegler experiment that training enhances formal operations logic.

Using 60 fifth grade students in two public schools, we replicated the Siegler, Liebert, and Liebert study and found that Siegler's training procedures did lead to enhanced performance on a pendulum task designed by Siegler, administered immediately after training and utilizing a carefully structured data sheet to record results. (This result was expected). However, we found that performance on a transfer task which utilized a data sheet in a new format was only slightly better for trained Ss than for untrained Ss. On a delayed test utilizing the Inhelder and Piaget Pendulum task (1958), performance of trained Ss was no better than performance of untrained Ss.

Based on our results, we believe that the Siegler training enables students to follow a memorized algorithm but we do not believe that the training results in the ability to "exercise formal operations logic." Neither do we think that the kind of training used by Siegler has much educational value, in spite of the fact that it is commonly seen in school settings.

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IMMEDIATE AND LONGITUDINAL EFFECTS OF  
A METRIC EDUCATION PROGRAM

Richard J. Rezba  
John Van de Walle  
Nancy Boraks

Virginia Commonwealth University  
Richmond, VA 23284

The major objective of the study was to examine the effects of a metric instructional program on the metric knowledge and attitude of 44 preservice teachers. In addition, an examination was made of the effect of experience in teaching metric measurement to elementary pupils on the metric knowledge and attitudes of the preservice teachers. In the follow-up study, begun in the spring of 1978 and still in progress, the effects of metric instructional experiences on preservice teachers' metric knowledge, attitudes and teaching skills is being examined by readministering tests and by examining their pupils' metric gains.

The study involved two groups of junior year preservice elementary teachers -- one group was enrolled in the science component of a methods block that permitted a weekly field experience, while the other group was enrolled in a non-block science methods course without a field experience. Both block and non-block groups received the same metric instruction, but only the block group was able to design and implement metric instruction in their field placements later that semester. In the longitudinal phase of the study, both groups of preservice teachers have implemented metric instruction during subsequent student teaching experiences.

Instruments and data sources used in the study included:

- 1) Metric knowledge test
- 2) Metric attitude inventory
- 3) Lesson plan checklist
- 4) Pupil pre/post data on teacher constructed metric tests.

The metric knowledge and attitude instruments were administered to both groups as a pre and posttest; as a delayed posttest (following metric instruction of pupils by the block group only; and later as post student teaching tests in subsequent semesters in which both groups implemented metric instruction.

Metric implementation data (e.g. lesson plans, tests, pupil scores, and supervising teachers' opinions) were collected on the block group during their pre-student teaching field experience and on both groups during their student teaching experience.

Analysis of the data included both case study and statistical techniques. (Analysis of variance).

Statistical analysis of the data revealed the following:

- 1) There were no significant differences between groups in pre or post metric knowledge or attitudes.
- 2) There were significant gains in both knowledge and attitude for both groups.
- 3) There were no significant differences between groups on their delayed posttest metric knowledge and attitudes (following metric instruction of pupils by the block group only). The metric knowledge of both groups increased over time. Metric attitude, however, increased for the block group and decreased for the non-block group.

Case study findings included:

20% of the two groups exercised their right to refuse to participate in the followup study.

Both groups were skillful in writing or selecting appropriate metric objectives. However, the block group, with previous implementation experience, has less difficulty in writing valid test items.

Neither group wrote detailed, organized lesson plans.

Considerable gains in metric knowledge and skills were evident from pupil scores, but no apparent differences were noted between pupils taught by block and non-block groups.



SIMULATION OF CLASSROOM INSTRUCTION IN  
PHYSICS IN THE EDUCATION OF TEACHERS IN DORTMUND

D. Nachtigall

PH Ruhr Dortmund  
Dortmund, West Germany

In order to provide future physics instructors with concept elements of their future profession early in their education, Dortmund introduced the physics workshop five years ago. The team conducting the workshop felt that it could be regarded as an interesting didactic alternative in the college-level education of instructors. This paper presents the education-theoretical background of the efforts and the resulting goals of the workshop, its organization, the various roles of the participants, and some important didactic issues introduced into the workshop. Emphasizing these aspects facilitates the discussion of generalizability to other subjects or to integrated projects, such as training in teaching, life science, and physics and technology.

The workshop represents an attempt to combine educational theories with practical physics in classes aimed at an understanding of the environment. In addition to a laboratory with gas, water, electrical hook-ups and a well-arranged collection of expensive devices for experimentation, a physics class should include up-to-date, meaningful situations from everyday life from which the phenomena of physics are extracted and upon which physics is based. The physics class should involve thinking, with its cognitive and affective components, interaction with objects, fellow students, the teacher, and other human beings in order to provide experiences as joint and challenging adventures for all participants.

The main goal of the workshop, therefore, was to confront the participants with situations in which such experiences become practically possible and can be used as a potential starting point for didactic theory elements. The students played different roles in the workshop. For instance, in the roles of pupils they may have had to try to identify with the intellectual level of 14 year olds, and to understand and express the feelings of 14 year olds in any given class situation.

This might include expressing boredom, or converting the fascination of an experiment into emotional or cognitive reactions.

In the role of the instructor, they conducted classes with the students in front of a camera.



In the roles of recording clerks, they recorded individual aspects of teacher and student behaviors.

In the role of the discussion leader, they guided the interpretation of the presentation, structured the discussion according to focal points, strived for balance, maintained a harmonious atmosphere, and summarized the results of the discussions.

In the role of the college students, they prepared their presentation, participated in the discussions and recorded the experience of their presentation, including the discussion, protocol, and the theory-practice experience in the final lesson outline.

The workshop instructors assumed various roles during the workshop. Based on their own practical teaching experience and theoretical background, they acted as advisors during the preparatory phase. During the first hour of the workshop they functioned predominately as conveyors of knowledge, theories, models, and concepts. As fellow pupils in the classroom, the workshop instructors sensitized the students, through their own behavior, to the cognitive and emotional aspects of pupil behavior in actual situations. The workshop instructors served as commentators offering suggestions on teacher behavior, suggesting alternative methods, and occasionally acting as teachers during the simulation. The workshop instructors also came into action as facilitators during the discussion phase which lasted two hours.

The evaluation of the observations from these simulation activities leads to the conclusion that the workshop has two important effects:

- 1) It reduces the practice shock when entering the teaching profession; and,
- 2) It provides more security in defending innovative ideas against school administrators who adhere to traditional concepts of school.

The analysis and interpretation of the classroom observations data collected during the workshop also resulted in discussion and research into various sociopsychological functions.

SCIENCE 9: AN ATTEMPT TO INTEGRATE  
SCIENCE, MATH, AND READING SKILLS

Myrna C. Thomas  
Harry A. Simon

Mamaroneck High School  
Mamaroneck, NY 10543

In the fall of 1975 a new skills-oriented ninth grade science course was introduced at Mamaroneck High School. The need for such a course as a pre-requisite for biology was perceived by both teachers and counselors. It had been noted that ninth graders with low to middle reading ability had difficulties with biology texts and with conceptualization. Also, these students reported that they found General Biology too easy and Regents Biology to be too difficult. The planning of such a course coincided with the decision of the Mamaroneck Board of Education to emphasize the acquisition and application of basic skills eg. math, writing, and reading.

"Science 9" was first introduced during the academic year 1975-1976. The criteria for placement included:

- 1) reading scores on the DAT's falling between the 45th and 75th percentiles
- 2) weakness in math skills
- 3) lack of the necessary study skills and/or maturity

The assignment of the appropriate students is made by the middle school (seventh and eighth grade) counselors. Built-in flexibility allows students to move into Regents Biology or to General Biology upon recommendation of the teacher.

The curriculum of Science 9 emphasizes basic skills with science content serving as the vehicle by which the acquisition and practice of these skills is achieved. The methods of science are stressed: students carry out experiences dealing with the investigation of a problem, the gathering of data, the treatment of data including graphing, table construction, and the use of math. These activities are followed by the students applying these techniques to several scientific disciplines. Other skills with which Science 9 is concerned are: note taking, outlining, recalling information; and correlating reading and demonstration with lecture material.

Each year pre and posttests are used to evaluate the course and to monitor the students' progress. These are conducted by the Science Department in conjunction with Dr. Margery Bernstein, Director of the Department of Program Evaluation and Research at Mamaroneck High School. Each year both the course and the testing instrument have been refined and revised. In 1978-1979 a completely objective test which included some specific topics such as density and metric conversions was introduced.

In order to evaluate the curriculum, seven objectives were set by the faculty. In 1978-1979 there were 203 students enrolled in the course in ten classes taught by six different teachers. The evaluation of each of the objectives is based on a locally devised test which was given in September and May. One hundred and seventeen (71%) of the enrollees completed the pre and posttests. The results show that there were gains for all the objectives with the exception of the objective which relates to reading scientific material. Moreover, the testing instrument shows a statistically significant increase in six of the seven objective skills and therefore the Science 9 course has been successful in meeting the established criteria.

A follow-up study is currently being made to follow Science 9 students throughout their four years of high school in order to determine their election of and success in further science courses.

THE RELATIONSHIP BETWEEN EXPERIENCE WITH HAP ACTIVITIES AND THE  
CONTENT-ACQUISITION OF SELECTED HEALTH EDUCATION TOPICS

Livingston S. Schneider

University of California at Berkeley  
Berkeley, CA 94720

The Health Activities Project (HAP) has developed approximately 60 activities for health education. Those activities are science-based experiments and/or simulations that provide the students the opportunity to discover for themselves concepts pertaining to health education. The data used for these discoveries is collected by the students through actual first hand experience with objects, situations and/or events.

An attempt to determine the effect of experiencing activities from HAP Set II on the students' comprehension of selected health concepts was made by interviewing students who had various amounts of experience with HAP II. The interview also attempted to explore the students' attitudes toward handicapped persons' ability to perform tasks not directly related to their handicap. A specific protocol was developed and administered to a random sample of HAP II students. The students' responses were then compared to their experience with the activities.

Purpose

The purpose of the HAP II Content Interview was to determine whether students who experienced HAP II activities understood the health concepts inherent to those activities better than students who did not experience the activities. The anticipation was that the experience of the activities would affect the manner in which a student would respond to problems, situations and/or new discoveries related to HAP II health concepts.

Measuring the Dependent Variable

The interview consisted of four content areas from HAPPII:

- 1) Body Temperature;
- 2) Growth and Development;
- 3) Attitudes Toward Handicapped Persons' Abilities; and,
- 4) Balance and Movement.



These areas were considered representative of HAP II and were chosen because the degree to which the students understood the concepts appeared to be measurable.

Items for the Content Interview were designed to evaluate a student's understanding of a particular health concept. They were carefully designed not to be dependent upon specific events that the student would likely have experienced as a result of HAP II activities. They did, however, challenge the student to observe, predict, and explain events related to HAP II concepts as they occurred within the context of the interview.

#### The Independent Variables

The amount of time that had elapsed between the date the student had experienced the activity and the date of the interview was recorded. The students' "Conservation of Volume" was measured using a task designed by Piaget and Inhelder and was used as a measure of intellectual development. Demographic data of age, sex, grade were also collected.

#### Analysis of the Data

Due to the nature of the responses, two different methods of analysis were used. When the dependent variables were measured on an interval scale, a multiple regression analysis was performed. For those items where that was not feasible the responses were analyzed using a chi-square analysis. The analysis was conducted for the entire sample and for each grade from 4 to 8.

#### Summary of the Responses for the Content Interview

The analyses of the responses made by the students to the items on the Content Interview indicated that experience with HAP II activities contributed toward the students' understanding of health concepts. While not all items demonstrated a significant difference between students who had experienced HAP II compared to those who had not, the data indicated that experience with HAP II was related to the content-achievement of the health concepts measured by the interview.

- 1) The concept of the body creating a layer of warm air around it and that wind replaces that layer with cooler environmental air was more appropriate for the upper grades.
- 2) Experience with HAP II was related to the number of responses offered when asked to compare drawings of the same person at different ages. The students' reasoning level was related to their ability to express those differences in terms of body proportions.



- 3) Experience with HAP II was directly related to the perception of a handicapped person's ability to perform a task not related to that handicap.
- 4) Experience with HAP II was directly related to the ability to explore why selected tasks are physiologically difficult to do.

ANALYSIS OF AN INSTRUCTIONAL UNIT  
FOR COGNITIVE LEVEL OF DEMAND

Ann C. Howe

Syracuse University  
Syracuse, NY 13210

Beulah P. Durr

William Nottingham High School  
Syracuse, NY 13210

Introduction

Recent Piagetian research has called attention to the wide range of cognitive levels to be found among students in secondary science classes and has shown that the cognitive level of many students is below the level demanded by much of the curriculum. Although it is clear that we need to make a better match between the cognitive levels of students and the cognitive demand of the curriculum, much practical work remains to be done in this area.

The problem has been attacked by several investigators. Karplus et al. (1977) and Herron (1975) have suggested guidelines for determining the cognitive level required to master a variety of topics in the curriculum. Lawson and Renner (1975) showed that concrete operational students did not master content classified as formal operational. Shayer (1978) analyzed several sections of the Nuffield Combined Science materials, using data collected from several schools, and showed how this method could be used in matching curriculum to pupils. We have sought in this study to carry this line of work forward.

Purpose

The purpose of the study was to analyze a unit of the chemistry curriculum for cognitive level of demand. We used predetermined guidelines to predict the cognitive levels required to master various aspects of the unit and tested our predictions by using Shayer's (1978) method of analysis.

### Method

The cognitive levels of all pupils ( $N = 82$ ) in four chemistry classes in an urban high school were determined by means of group administered tests. Pupils were categorized as concrete, transitional, early formal, or late formal operational.

After the unit of instruction (the mole concept) had been selected, instructional objectives were determined. These included concepts, generalizations, and problem types covering the various aspects of the topic. The unit was taught to all classes by one teacher using a method of instruction developed and tested in a previous study (Durr and Howe, 1979).

At the end of the unit, attainment of the objectives of instruction was assessed by a test composed of 24 items selected from tests prepared by national and state groups for use with secondary students. Test items were chosen to correspond with specific objectives of instruction. The cognitive level of each item was predicted by reference to guidelines previously established.

### Analysis of Results

Results were analyzed by determining the percent of students at each Piagetian level who correctly answered each item. This allowed us to assess the cognitive level of demand of the instructional objectives and to compare the observed levels with the predicted levels.

### Discussion

An analysis of this kind gives the teacher the information needed to form reasonable expectations for individual pupils and to begin to match the curriculum to the pupils.

This study demonstrates the applicability of an empirical method of curriculum analysis. Although the work is painstaking, it is not difficult nor disruptive of classroom routine and the results of the analysis are immediately useful to the teacher. If more teachers could be persuaded to work with science educators -- or on their own -- to make similar analyses of other sections of the curriculum we would have both a theoretical basis (i.e. Piaget's work) and an empirical basis for making curriculum decisions.

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LEARNING CHEMISTRY AND SCIENTIFIC METHODS  
AND PROCEDURES THROUGH BIOCHEMISTRY -- A

FORMATIVE EVALUATION

David F. Treagust

Michigan State University  
East Lansing, MI 48824

John T. Cody

University of Iowa  
Iowa City, IA 52242

Rationale and Objectives

The rationale for the investigation was based on the hypothesis that students would significantly increase their knowledge and understanding of inorganic and organic chemistry by learning biochemistry. Similarly it was hypothesized that the incorporation of a research proposal and laboratory investigations, which were more extensive and required more critical thinking than typical cookbook labs, would significantly increase students' knowledge and understanding of the methods and procedures of science.

The major objective of this investigation was to examine whether or not teaching biochemistry (higher-order content) would result in substantial learning of chemistry (lower-order content) and of the methods and procedures of science. The evaluation was repeated over the three years of the program's existence in attempt to examine the consistency of the results with different groups of students.

Methodology and Design

The study utilized a one-group pretest-posttest design; there was no intention of comparing treatment with control groups. The time lapse between the pre and posttest was approximately six weeks. The statistical analysis involved the use of the Wilcoxon matched-pairs signed-ranks test to examine a significant increase or decrease in student response between pretest and posttest scores.



The subjects were high-ability high school students enrolled in a secondary science training program during the summer at the University of Iowa. Students spent approximately six hours per day being directly involved in some aspect of the program; lecture-discussion sessions were held at the beginning of each half day followed by laboratory or library work.

The same program, with revision and updating, was presented to similar groups of students in the summers of 1976, 1977, and 1978.

#### Instruments and Data

The American Chemical Society (ACS) Inorganic-Organic-Biological Chemistry Test Form 1974 was used to evaluate subject matter competency in the three areas of chemistry; the Methods and Procedures of Science (MPS) test was used to measure the understanding of the methods and procedures of science. Reliabilities for the separate inorganic, organic, and biological chemistry section of the ACS Test were established at 0.90, 0.68, and 0.85 respectively; the reliability for the MPS Test was established at 0.775. Norms for the ACS Test were based on students from introductory college courses; norms for the MPS Test were based on students in grades 9 to 11.

#### Results and Conclusions

The analysis of the data over the three summers was relatively consistent and showed that the students in the biochemistry course had statistically significantly improved their understanding not only of biological chemistry but also of organic and inorganic chemistry and of the methods and procedures of science. The consistent results over the three summers would appear to imply that teaching this type of biochemistry course (higher-order content) to high ability high school students is a viable means of teaching chemistry (lower-order content) and the methods and procedures of science.

## A DEVELOPMENTAL STUDY OF THE CONCEPTS OF

## HEAT AND TEMPERATURE IN 9 TO 13 YEAR OLDS

Michael Shayer

Chelsea College: University of London  
London, England SW6 7SR

It appears to be a matter of some dispute between Ausubelians and Piagetians as to whether children develop specific concepts in a hierarchy by the same or by many different personal routes. If a sample large enough and sufficiently varied in ability can be investigated a critical test is possible.

The study to be described made use of three inputs. The development of a technique of "psychometrising Piaget" by an English team based at London University provided a way of extending a study by Erickson (1977) of personal conceptual inventories to testing a sample of 200 children by a 60 item demonstrated group test. In addition a team of curriculum developers had provided a tentative list of objectives for the teaching of heat to middle school students. The schools in which the study was carried out wished to know which of the objectives were more suitable for 9 or for 12 year olds. The group test utilized descriptors both from the Erickson study and from the list of curriculum objectives.

In addition to the heat test a Piagetian group test (NFER, 1979) in the area of volume and heaviness was administered to see whether the development of concepts of heat could be mapped onto Piagetian stages of development.

Test items in nine aspects of heat were written, with some of the experiments to be demonstrated to the class. These aspects included conduction, expansion, composition of heat, temperature scales, changes of state, etc.

A factor analysis of the data showed that one factor was sufficient to explain the common-factor variance of the heat scales, and that the heat test was also unifactor with the Piagetian test. In addition the regression of Piagetian level, sex and school year onto level on the heat test showed a slight sex differential in favor of boys, and a non-significant difference in the age developmental

rate between the heat and the Piagetian levels. It was possible to describe early concrete, late concrete and early formal levels of understanding in the area of heat and temperature.

In this particular case it appears that the hypothesis of a number of different developmental paths, dependent on previous experience cannot be sustained. It is not claimed that this would be true of all cognitive development, particularly where culture-specific myths are involved.

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A STUDY OF THE COGNITIVE AND AFFECTIVE IMPACT  
ON INSERVICE TEACHERS PARTICIPATING IN AN INTENSIVE  
ENVIRONMENTAL EDUCATION INSTITUTE/WORKSHOP

Louis A. Iozzi  
Arthur W. Edwards

Cook College, Rutgers University  
New Brunswick, NJ 08903

Objectives and Rationale

Teacher inservice education programs have been utilized as the dominant approach to updating knowledge and teaching methodologies of educators in all fields. While such practices have generally been regarded as effective, few studies have attempted to determine whether such experiences also result in a positive impact on the inservice teacher's own life-style.

While it is important for teachers of all disciplines to exhibit behaviors appropriate to and exemplary of their profession, it is critical for the educator who attempts to teach environmental education or environmental science. Surely, the environmental educator who employs a "do as I say not as I do" approach is quickly "exposed." It is highly questionable whether such an individual can have a significant impact on students.

While a highly effective inservice teacher education program provides educators with the latest methodologies and techniques of a particular field, it should also impact both on the so-called cognitive and affective domains; that is, such an experience should in addition motivate teachers to change their behavior.

A summer institute/workshop was conducted at Cook College, Rutgers, The State University of New Jersey, during the summer of 1979. The four week, five credit hour course was open to inservice teachers of all disciplines at all grade levels.

The course was designed to expose teachers to a wide variety of environmental problems endemic to New Jersey in particular and to the Middle Atlantic states regional area in general. Activities were designed to promote cognitive and affective growth related to environmental issues and to introduce new methodologies for translating those experiences into classroom application.



In addition to the more than thirty Cook/Rutgers faculty members on the summer institute staff, members of the business/industrial sector and representatives from federal, state, and private organizations contributed their expertise. Thus, the total "faculty" exceeded 100 experts from various disciplines with varying environmental orientations and offering a wide range of viewpoints.

The objective of this study was to determine the success of this intensive course format and content in promoting positive environmental growth in both the cognitive and affective domains. More specifically, as a result of participating in the summer institute workshop, did the participants exhibit significant pretest changes in:

- 1) growth in knowledge about environmental issues?
- 2) change in affect (emotionality) regarding environmental problems?
- 3) change in verbal commitment regarding efforts to improve environmental quality?
- 4) change in actual commitment (behavior) regarding the improvement of environmental quality?

#### Methodology and Design

A quasi-experimental design (pretest-treatment-posttest) was employed in this study. The 29 inservice teachers enrolled in the 1979 summer institute workshop were administered a pretest on the first day of the workshop. At the conclusion of the workshop, a posttest was administered. A comparable control group was unavailable.

#### Instrument and Data

The Ecology Attitude Inventory (Malony and Ward, 1973) used in this study included four subscales:

- 1) Environmental Knowledge
- 2) Environmental Affect (emotionality)
- 3) Verbal Commitment
- 4) Actual Commitment (behavior)

The authors reported reliabilities (Cronbach's Alpha) for the scales as .85, .81, and .89 for Affect, Verbal Commitment, and Actual Commitment, respectively. Internal consistencies using Scotts Homogeneity Ratio were .358, .296, and .442 for Affect, Verbal Commitment, and Actual Commitment, respectively. A Pearson Reliability Coefficient of .89 was reported for the knowledge scale.

A biographical questionnaire was employed to obtain personal data related to age, sex, ethnic group, etc., of the sample.



### Results and Conclusions

The results of this study indicated that the participants in the summer institute workshop achieved significant pre to posttest gains on all four subscales of the Ecology Attitude Inventory. In addition, a number of highly significant correlations between the four subscales and inservice teacher personal characteristics were revealed.

More specifically, this study showed that:

- 1) The workshop format and content employed were highly successful in producing significant cognitive and affective growth in environmental education.
- 2) A relatively short intervention (four weeks) can produce positive environmental life-style changes in adults.

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AN EVALUATION OF THE UNIVERSITY OF WASHINGTON PROGRAM  
IN PHYSICAL SCIENCE AND SCIENCE TEACHING  
FOR ELEMENTARY SCHOOL TEACHERS

Jim Minstrell

Mercer Island High School  
Mercer Island, WA 98040

This study was an evaluation of the effectiveness of the 1973 and 1974 summer versions of a teacher training program jointly developed by the University of Washington Physics and Education Departments.

Through the use of four instruments developed by the evaluator, data on teacher behavior was gathered and used to assess the attainment of the program goals. A Survey of Science Teaching Characteristics enabled the evaluator to identify changes in teachers' perceptions of their science teaching behavior. From classroom observations and audio tape recordings, the Classroom Observation Instrument was used to identify changes in student activity, the General Coding Scheme for Science Lessons was used to identify changes in teacher verbal behavior, and a Wait-Time Code was used to identify changes in the teachers' listening behavior. Pre and post program observations were conducted two months prior to the program and eight months after the program, respectively. Naturally occurring opportunities to control competing variables resulted in the employment of five analysis designs to test the effects of the program. Significance was set at the .05 level. The General Code and Wait-Time Code were also used to describe verbal interaction of the summer institute instructors.

The following is a list of the seven program goals and the observed results related to those goals. The teacher participants were expected to:

- (1 and 2) Increase understanding of the concepts of science and increase interest in science and science education.

Survey results suggested that the teachers perceived that they had changed in ways consistent with these two and the other five goals. However, the evaluator collected no observations from which to decide whether the teachers actually changed behavior in accordance with the above two goals.

- 3) Increase emphasis in appropriate student activities for learning science

There were significant decreases in science lesson time spent watching demonstrations, reading, and listening to lectures.

- 4) Increase emphasis on use of questioning and improvement of questioning techniques.

Teachers significantly increased their use of questioning in general. While there appeared to be a change in the direction of increased wait-time, there was not a significant increase according to the 3-second wait criterion.

- 5) Increase emphasis on appropriate questioning for gaining knowledge in science.

Teachers significantly increased their use of concrete, rational, non-arbitrary, non-authority based ways of generating knowledge in science. Teachers significantly decreased their questioning and telling about arbitrary signs, symbols, names, and definitions.

- 6) Increase emphasis on appropriate behavior for aiding the intellectual development of children.

Teachers significantly increased their use of higher level questions and significantly decreased their use of statements relating to classroom management and control of students.

- 7) Increase emphasis on communicating clearly and on using terms from prior experience.

Teachers significantly increased their questioning for clarification of meaning and significantly decreased their questioning for information without a concrete base.

Since this program effected behavior changes supportive of goals that are consistent with national priorities, the program was judged to be valuable for educating elementary school science teachers.

MEASURING TEACHERS' ATTITUDES ABOUT  
ENERGY AND RELATED MATTERS

Durward Richardson  
Linda Johnson

East Texas State University  
Commerce, TX 75428

Rationale and Objectives

Americans continue to search for a villain to blame for the inconvenience, shortage, and higher prices caused by a lack of available energy at an economical price. Few Americans have a good understanding of the details of recent governmental actions in creating energy education programs to provide an informed populace. Teachers in particular have a responsibility to be informed on current conditions in all segments of our society. Because of this need, the government and various energy producers are providing financial support to colleges and universities for the purpose of conducting energy education workshops for teachers. A survey of available print media indicates that little or no research is being done to investigate the effectiveness of these programs, and apparently none is being done to determine attitudinal change taking place among the participants. Because of this absence of evaluation effort, there is an identified need to investigate the effectiveness and value of these programs and to report the findings. In response to this need a study was initiated to measure attitudinal change of participants during the various workshops being conducted on four university campuses.

The objectives of the study were:

- 1) to design a Likert-type scale for measuring teachers' attitudes about energy and related subjects;
- 2) to pre and posttest participants in five different programs conducted at four separate locations;
- 3) to apply statistical procedures in determining significant changes in attitudes about energy and related matters as a result of participation in energy education workshops.

Design

Initially, an item pool of 85 Likert-type items was constructed with a five point strongly agree to strongly disagree response continuum.



The instrument was administered to 205 individuals enrolled in graduate teacher education courses. Intercorrelations of the 86 attitudinal items were computed across all 205 respondents. Factor analysis was employed using a varimax criterion (orthogonal rotation) of the factor matrix. Twenty-nine factors, accounting for 78% of the common variance, were extracted with several factors having multiple loadings and 19 items loading singly.

Each factor was evaluated by knowledgeable individuals to determine if the factor should be included. In addition, each rater identified the item (loading) that should be used to measure the factor where multiple loadings were present. Relevance to the overall attitude domain, discriminability, length of item, and resultant loadings were employed in arriving at the nineteen items included in the final form. No item was included with a factor loading less than .5, while most included items had loadings in the .7 to .8 range.

The instrument was then administered in a pre and posttest format to all participants in energy education workshops being conducted during the summer of 1979 at four area universities. A t-test was utilized to compare the two related means of each group to determine the probability that the difference between the means was a real rather than a chance difference. Other variables considered were sex of participants, subject matter taught, and grade level taught. A null hypothesis was tested in each individual case.

#### Results and Conclusions

The resulting nineteen item instrument did in fact measure various constructs related to attitudes about energy and energy related matters. All but one group moved toward a definite and significant pro-energy position where attitudes were concerned. Analysis of data related to sex, grade taught, and subject taught was made.



EFFECTS OF INSTRUCTION IN MEASUREMENT PROCESSES  
ON ATTITUDE, KNOWLEDGE, PLUS MEASUREMENT  
AND ESTIMATION SKILLS UPON INSERVICE PROFESSIONALS

Michael Szabo  
Cecil R. Trueblood

The Pennsylvania State University  
University Park, PA 16802

The present research examines the effect of measurement instruction (metric) on attitude, knowledge, and skills of measurement and estimation. The sample consisted of inservice teachers and administrators K-12. The context of the instruction was a series of workshops to train teams of leaders who were school-based and willing to train others (colleagues, administrators, students, community) in metric measurement skills dealing with length, area, volume, mass and temperature. In addition to staff training, the leadership teams were to design exemplar metric instruction, revise curriculum guides, and develop multi-year changeover plans to incorporate the metric system of measurement.

The treatment consisted of providing instruction designed under funding from the Metric Education Office. The instruction was:

- 1) diagnostic and prescriptive, with embedded diagnostic assessments;
- 2) self-paced;
- 3) individualized; and,
- 4) based upon a manipulative mode.

The instructional package and model was designed to insure that each member of the leadership team would possess adequate measurement skills to enable them to carry out the above mentioned leadership tasks.

The design was a pretest/posttest treatment group field study with replication at various sites and levels. Data were collected from three separate school districts and from several leadership teams within those districts. In some cases, data were also made available from the staff members trained by the leaders. A minimal amount of data were available from students of the staff.

Instrumentation consisted of separate instruments to measure:

- 1) attitude toward metric measurement (Shrigley and Trueblood, 1979);
- 2) knowledge of metric measurement terminology;
- 3) measurement skills; and,
- 4) estimation skills.

In most cases, data were available on a pre and posttest basis and were analyzed using repeated measures ANOVA.

It was found that in the majority of subsamples, significant gains were made from pre to posttesting. The variable most frequently subject to gains was metric attitude. Dramatic gains in estimation skills, observed during the instruction, were not as dramatic as evidenced by pre/post gains. Substantial gains in measurement and knowledge skills were noted in many subsamples.

The results suggest further study of an experimental field study nature to confirm the findings regarding instructional approaches to measurement processes. Effective measurement instruction could make added time available for science instruction.

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VALIDATION OF THREE INSTRUCTIONAL MODES WITH CONSERVERS  
AND NONCONSERVERS OF LENGTH USING  
LINEAR METRIC MEASUREMENT

Susan R. Smith  
Cecil R. Trueblood  
Michael Szabo

The Pennsylvania State University  
University Park, PA 16802

This study attempted to gather empirical evidence to guide educators in their teaching of linear measurement to primary school children. More specifically, the study attempted to answer the question: What modes of instruction are most effective for teaching linear measurement concepts to conservers and non-conservers of length?

Sixty-six first and second grade pupils were randomly assigned to three treatment (T) groups. Each T group was composed of 11 conservers and 11 nonconservers of length as defined by Jean Piaget.

T1 was taught length measurement for one week under an abstract (symbolic--S) mode of instruction. T1 and T2 were taught for one week under a graphic (iconic--I) mode. And T1, T2 and T3 were taught for one week under a manipulative mode (enactive--E) of instruction. All student output was in the E mode. The modes are those defined by Jerome S. Bruner (1966).

A nine item test, designed by the investigators, was given the end of each week of instruction and constituted the dependent measures. This measured skills in linear measurement. Metropolitan Readiness Test scores from the pupils' school files were used as a measure of general mental ability (GMA). A test of length conservation similar to that described by Inhelder, Sinclair and Bovet (1974) was designed by the investigator to identify conservers and nonconservers.

The data analyses run on the dependent measures consisted of analyses of variance, correlations, and analyses of covariance using GMA as the covariate.

The findings and conclusions of the study include:

- 1) conservers had significantly higher ( $p \leq .05$ ) general mental ability scores than nonconservers;
- 2) conservers did not perform significantly better than nonconservers on the posttest;
- 3) posttest scores from the manipulative (E) instructional mode were significantly higher than scores from the graphic (I) mode ( $p \leq .05$ );
- 4) the differences between scores from the manipulative (E) mode week and the abstract (S) mode week was high but not significant ( $.05 \leq p \leq .10$ );
- 5) no significant difference was found between scores of conservers and nonconservers on the E posttest;
- 6) no significant difference was found between scores of conservers and nonconservers on the I posttest;
- 7) no significant difference was found between adjusted scores on the S posttest of conservers and nonconservers when GMA was accounted for via analysis of covariance; and,
- 8) no significant difference was found between adjusted iterative measurement subscores of conservers and nonconservers when GMA was the covariate.

The implications for educators are:

- 1) primary pupils, whether length conservers or nonconservers, can learn to measure with non-standard and standard units of length;
- 2) iterative measurement is a difficult concept for primary pupils regardless of their conservation status;
- 3) the manipulative instructional mode is more effective in introducing measurement concepts to first and second graders than the graphic and symbolic modes; and,
- 4) Piagetian conservation measures and IQ measures seem to overlap somewhat in their effect on learning.

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THE EFFECTS OF THREE INSTRUCTIONAL STRATEGIES  
ON PRESERVICE TEACHERS' ABILITY TO ESTIMATE  
LENGTH AND AREA IN THE METRIC SYSTEM

Barbara J. Attivo

University of Pittsburgh  
Johnstown, PA 15907

Cecil R. Trueblood

The Pennsylvania State University  
University Park, PA 16802

The purpose of this study was to investigate how the nature of metric estimation skill instruction affects prospective elementary and special education teachers' abilities to estimate metric length, area and volume. Four types of estimation skills were identified by an estimation matrix. These types were based upon the physical absence or presence of the unit of reference during the estimation process and the physical absence or presence of the object to be estimated. Specifically, the investigation sought to determine what effects learning one type of estimation skill (when object to be estimated is physically present and unit of reference is physically absent) for metric length and area to criterion had on the retention of these skills as well as on transfer to three other estimation types. Three instructional strategies were selected to develop this type estimation skill. The strategies employed were:

- 1) a personal reference unit;
- 2) a cut or drawn unit of reference which was put out of sight before making an estimate; and,
- 3) estimation without specifying an explicit strategy.

Forty-two hypotheses relating to the following six questions were tested:

Is one of the three instructional strategies more effective in reducing the estimation error for Type 1, 2, 3, and 4 estimation skills?



Does one instructional strategy result in a greater number of students mastering estimation skills for metric length and area?

What effect does explicit instruction to criterion in Type 2 estimation skill have on the acquisition of the remaining three types of estimation skill?

What effect does explicit instruction to criterion for Type 2 estimation skills have on the ability to improve Type 1, 3, and 4 metric length and area estimation skills?

What effect does explicit instruction to criterion in metric length estimation skills have on the ability to estimate metric area, and what effect does explicit instruction in metric length and area have on the ability to estimate volume in the metric system?

How are prospective teachers' ability to estimate length and area in the metric system before explicit instruction related to their ability to estimate length and area in the metric system after explicit instruction?

After a pretest, 126 subjects were randomly assigned to one of the instructional strategies for the duration of the investigation. Utilizing self-paced instructional materials students were instructed to criterion in Type 2 estimation skill for length estimation and area estimation skill. In this estimation skill type the unit to be used in making the reference was physically absent while the object was present. A criterion referenced mastery test was administered to determine mastery of estimation skill at the conclusion of instruction for the attribute. Mastery criterion was defined as estimates that were within  $\pm 15\%$  of the measured attribute on 80% of the estimates. Upon achievement of mastery, a Retention/Transfer test was administered to determine the ability to perform the other three estimation types.

Utilizing non-parametric statistical techniques the following conclusions were reached:

- 1) The personal reference strategy was significantly more effective than the unit reference strategy for the estimation type that was the same as the instruction;
- 2) No significant differences were detected in the number of students for each instructional strategy who achieved mastery criterion following instruction;
- 3) When students retained mastery criterion of the estimation skill for which they received instruction, they did not reach mastery criterion on the remaining types of estimation skills for the same attribute on the Retention/Transfer test;

- 4) For students who achieved mastery criterion during instruction, significant reductions in estimation error were noted for additional estimation types following instruction in length and area estimation skills for Type 2;
- 5) For all instructional strategies subjects' estimation error for area, after length estimation instruction was significantly improved as was the volume estimation error for students employing the unit reference strategy during area estimation instruction; and,
- 6) Correlations between pretest and the Retention/Transfer test were not significant.

METRIC ATTITUDE AND ACHIEVEMENT OF PRESERVICE ELEMENTARY  
TEACHERS AS A FUNCTION OF THREE INSTRUCTIONAL APPROACHES

Michael Szabo

The Pennsylvania State University  
University Park, PA 16802

Prasit Kongsasana

Chulalakorn University  
Thailand

The purposes of this study were to:

- 1) determine if preservice elementary teachers' attitude toward the metric system can be improved by completing metric units of instruction embedded in a methods course; and,
- 2) investigate relationships among three types of training, attitude, and learning.

The sample was comprised of 126 students in an undergraduate methods course at The Pennsylvania State University. Students were randomly assigned to one of three treatment groups and each took a knowledge and attitude pretest. After the students completed the metric instruction modules, they were posttested on knowledge and attitude.

Independent variables included the specific modules of metric instruction with the three treatments embedded. The main dependent variable was metric attitude. Additional criterion variables were length, area, and volume estimation skills.

The hypotheses of this study were tested through analysis of variance and the correlation techniques. The instructional treatments are described in the paper presented by Attivo and Trueblood.

First, there was a significant attitude gain for all who received instruction. This gain was observed in all three subscale scores as well as total. No differences in attitude scores as a function of the three types of instruction were observed.

This study led to the following conclusions. There were differences between three levels of metric achievement on a measure of metric attitude score (Impact of Changeover on Self) for preservice elementary teachers who acquired competency in the metric modules. This difference was not observed on the total attitude score or on the other two subscales (Impact of Changeover on U.S. and Present Ability to Learn to Use Metrics).

Next, there were no correlations between three levels of metric achievement on a measure of metric attitude score or on Subscales 2 and 3 for preservice elementary teachers. The results for Subscale 1 suggest higher attitude scores for those with high metric achievement scores.

Finally, there were no significant correlations between achievement scores on length or area estimation skills and post attitude scores for those who did or did not master selected types of estimation skills. There were no differences among Type 1, Type 2, or Type 4 correlations between length or area estimation skills and post attitude scores. There were no significant correlations between achievement gain in length, area, or volume estimation skills and post metric attitude scores.

It appears that specific instruction to train preservice teachers to measure and estimate in metric units increases at least some dimensions of their attitude toward the metric system. Differences in metric instructional format did not result in different attitudes. Finally, post metric attitude did not seem to be a function of the amount of metric skills acquired.



A COMPARATIVE STUDY OF CHEMISTRY STUDENTS'  
PERCEPTION OF THE LEARNING ENVIRONMENT IN HIGH SCHOOL  
AND VOCATIONAL SCHOOLS

Ruth Ben-Zvi  
Avi Hofstein

The Weizmann Institute of Science  
Rehovot, Israel

Rationale and Objectives

The science classroom and laboratory are key places where intentions are transformed into actions and where both teacher and learner are involved in realizing the curriculum objectives. In a recent article by Yager (1978) it is recommended to include the classroom climate in educational research as a part of the transactions which take place in the class.

An important contribution to the understanding of the role of the learning environment was made by Anderson (1973) who developed the L.E.I. (Learning Environmental Inventory), a measure of classroom climate. The L.E.I. was found to be a good predictor both for students' attitude and achievement (Welch, 1973).

The present study is an attempt to gain more insight into the validity of the L.E.I. as a measure of classroom climate by comparing the perception of two different groups of chemistry students. It was hypothesised that specific differences in perception of classroom learning environment could be attributed to differences in ability, teaching strategies and reasons for studying chemistry.

Instruments and Methodology

The L.E.I. consists of the following 15 scales: Difficulty, Speed, Apathy, Satisfaction, Cohesiveness, Disorganization, Competitiveness, Diversity, Democracy, Friction, Goal Direction, Favoritism, Environment and Cliqueness. A modified version of the instrument was used in the present study in which a chemistry connotation was given to most of the items.



The inventory was given to two entirely different groups of 11th grade students who learn chemistry; a group of high school students (N = 235) from eight classes and a group of students studying chemistry in vocational schools in order to become laboratory technicians (N = 115) from eight classes.

There are several differences between the groups which it is hypothesized could contribute to students' perception of classroom learning environment:

- a) Ability: Usually those who choose to study in vocational schools are less able students.
- b) Class size: Classes in the vocational school on the average are smaller than in a regular school.
- c) Reasons for study: For the high school students, chemistry is one out of many subjects they learn while for the laboratory technicians the studies of chemistry are a preparation for their future career.
- d) Curricula: The curriculum studied in high schools is concept oriented and the laboratory experiments are usually of the problem solving type, while the laboratory technicians' curriculum is comparably loaded with facts and bits of information.

#### Results and Discussion

A multiple discriminant analysis was used to gain weights for the 15 scales of the L.E.I. The value of Wilks' Lambda associated with the one discriminant function separating the two groups was 0.64 and the value of chi square was 152 (df = 15  $p < 0.001$ ). These results support the hypothesis that the two groups differ in their perception of the learning environment.

In order to get more insight into the differences a series of t-tests were carried out for each of the scales. It was found that the laboratory technicians rated significantly higher on six out of 15 of the scales: Formality, Speed, Goal, Direction, Satisfaction, Democracy, and Difficulty and significantly lower in Disorganization, Apathy and Competitiveness.

These differences will be discussed in relation to the differences existing between the two groups.

From the results obtained it can be concluded that the L.E.I. is a sensitive instrument for detecting differences in ability, in the curriculum studied and also in the career expectations of the students.

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## APPLICATIONS OF SCIENCE PROCESSES

### BY ADOLESCENTS USING MICRO-COMPUTERS:

#### PART I, ESTIMATION

Carl F. Berger  
Richard Newman  
Dorothy Cox

University of Michigan  
Ann Arbor, MI 48109

The use of the micro-computer to examine adolescents' problem solving skills, particularly their skills involving science processes, has just begun to be examined. The use of a micro-computer to not only present information but to gather data presents a unique feature available to science education researchers. In this experiment, adolescent students' use of estimation in solving a problem presented on a micro-computer is examined. Three levels of increasing difficulty, each containing ten problems, are presented. The times and number of estimations to correct criteria are recorded. The average time per estimation per problem is used as measure of the process aptitude. Learning strategies are examined, and learning curves are described.

#### Rationale for the Study

Use of micro-computers in providing knowledge has initially been studied; however, the use of micro-computers to assist in the development of science processes presents a new and challenging field. In this experiment, the process of estimation as defined by the Association for the Advancement of Science was used. The importance placed on problem representation, in particular the spatial and imagerial aspects of display, is pertinent to the present study of learning estimation skills. Further, Rowe has discussed general approaches to problem solving in science processes under the rubric of fate control. This refers to a person's sense that he or she can to some extent influence the direction of their own destiny. It is the question of fate control versus fatalism. Rowe refers to two metaphorical examples of the N points that are fate-control modeled. First is the craps shooter, who can be characterized as not being a very strategic or planned problem solver, in contrast to a bowler, who is an active, systematic, and persistent information processor. Using these

elements of information storage retrieval and strategies, the experiment designed attempted to measure strategies students used in estimation and to find out if the amount of information presented to the student increased or decreased their ability to use strategies or their ability to solve problems in a reasonable length of time.

#### Methodology and Design

The simulation games used for studying adolescents' estimation skills on a micro-computer involved a vertical line appearing on the right side of a CRT micro-computer screen, with an "O" representing a balloon and appearing adjacent to the line. The numbers 0 and 100 appeared at the top and the bottom of the line. Students were informed that they were to estimate the height of the balloon on the wall. As students' estimations were entered on the computer, an arrow with a trailing dash appeared at the left of the screen, moved to right, sticking to the "ball" at the height of the estimation. In the lowest level of difficulty, Level I, the estimated value appeared on the left with a dash line between that value and the dart on the wall. The second level of difficulty showed the value but no dashed line. Level III, the most difficult, showed only a dart on the right with neither the dashed line nor the value on the left. As students set about hitting the balloons, data were recorded on the time taken to make each estimation and the value of the estimation. From these data, the number of estimates per problem, average time per estimate per problem were computed and the strategy of approach was inferred. The strategy could be inferred by observing whether students used information from one problem to the next, or whether they treated each individual problem as new and unique. Three strategies were hypothesized: One, a ladder approach, hypothesized that students would approach the correct solution from either a low estimation or a high estimation. The second hypothesized that students would bracket the responses, first going low and then high, until the estimation was correctly made. The third involved no use of information and random approaches. The first two would correspond to a bowling technique; the third would correspond to a crapshooter technique. In addition, if students were learning from the use of micro-computers, it could be hypothesized that the times for estimation would decrease as students learned how to estimate quickly and that these times would continue to improve throughout the levels until the increasing difficulty of the problem would interfere with the learning process.

#### Instruments and Data

All data was gathered on the Apple micro-computer, although two other micro-computers were used -- the PET and the Radio Shack TRS-80 -- and no qualitative differences could be found. Data were gathered on ten adolescent students ranging in age from 12 through 14. Wide



academic abilities were noted as well as wide SES settings were noted, as the students came from a large suburban junior high school near Detroit, Michigan. Over 230 units of information were gathered representing more than 1,000 individual trials. Thus, though a small number of students participated, sufficient problems generated (10), levels (3), and observations (1,000) encouraged analysis by techniques other than single subject research design. The analysis techniques used were Nth order regression, analysis of variance, and matched pair analysis of variance. It may be of some interest to note that analysis was carried out on the micro-computer using programs adapted from BIO-MED and MIDAS routines.

### Results and Conclusions

Nth order regressions were used to fit a best estimate to the average time shown for each problem for the ten students. A third order regression best characterized the data for Level I and Level II. The correlations proved significant and for Level I were  $-.926$ ; for Level II a correlation coefficient of  $-.884$ ; and for Level III a nonsignificant correlation. In Level I, the least squares regression fit indicated that estimation started with long times, slowly shortened, and then leveled off, going from nine seconds to three seconds average estimation times. Second level followed the same pattern, going from 7 seconds to 2.5 seconds. For Level III, no significant difference could be found and wide variations occurred between problems, with an average time of 4 seconds. So, within the first two levels of DART (the name of the simulation game), estimation time did appear to improve across problems; but at the third level there did not seem to be this practice effect, and, indeed, the increase in average estimation time at the end of the experiment going from 3 seconds to 2.5 seconds to 4 seconds indicates that the lack of information for Level III may have prevented students from improving their estimation skill.

While all three strategies hypothesized in the design of this study were observed, the ability of students to quickly and accurately estimate the position of the balloon on the wall prevented careful interpretation of the strategies students used in problem solving. It should be left for further groups of children, perhaps at younger ages in elementary school, to determine if these strategies are more identifiable and build up over longer periods of time. The conclusions of the research indicate that a micro-computer may be used to analyze students' approaches to estimation, and indeed may prove a powerful tool for assisting them in developing skills in linear estimation of distance. Further information is needed, however, to find if the micro-computer may also be used as a tool for other science processes and if age differences can be measured using this new and powerful research and instructional tool.



THE RELATIONSHIP OF SERIATION BEHAVIOR TO ACHIEVEMENT IN  
READING READINESS, READING AND MATHEMATICS  
OF FIRST GRADE CHILDREN

Michael J. Padilla  
University of Georgia  
Athens, GA 30602

Seriation exercises appear to have found a home in early childhood science curriculum as evidenced by the inclusion of such activities in programs such as the Science Curriculum Improvement Study and the Modular Activities Program in Science. Yet with the recent strong emphasis on reading and mathematics instruction, many primary teachers find it difficult to find time for such "science" since they view it as not related to their prime goal, i.e., teaching reading and math skills. If a relationship between what is taught in science and achievement in math and reading can be shown to be causal to some degree, then finding time for science will be much less a problem. The present study takes the first step in this effort by looking for a relationship between reading readiness, reading and math achievement, and seriation achievement.

Design and Procedures

One hundred and twenty first grade children were pretested using a stick seriation task and classified as stage I, II, or III seriators. Twenty-four from each stage were randomly selected and eight of these were randomly assigned to each of three small group seriation treatments. Treatments 1 and 2 taught groups of four children different strategies for seriating nonvisual objects. Treatment 3 was a placebo group that worked only with the materials. Treatment occurred in four 15 minute sessions over a two week period. Seriation results due to treatment and stage are reported in Padilla and Ollila (1979) and will not be reported in this paper. Only the relationship of seriation ability to achievement is considered here.

### Data Collection

Four seriation tasks were given as an immediate posttest in February. The exact same tasks were given in May as a retention test. The Canadian Reading Readiness Test was administered the previous September and the Stanford Achievement Test - Primary I Battery (with total battery score and auditory, reading, and mathematics subtests) was given the following May. Reliabilities of the achievement measures vary from .83 to .90, while interrater reliabilities were .95 for the seriation scores.

### Analysis

The 9 pre, post and retention seriation task scores were intercorrelated with the reading readiness and four achievement scores for all 72 students regardless of treatment using Pearson's  $r$ . Of the 45 correlations obtained in this manner, 34 proved to be significant. The reading readiness score correlated significantly ( $p < .05$ ) with the pre, post and retention stick seriation scores (Range = .27 to .33). The achievement total battery score correlated significantly ( $p < .05$ ) with eight of nine of the seriation scores (Range = .26 to .48). On the achievement subtests the highest inter-correlations occurred with the mathematics results (Range = .30 to .56).

When the seriation-achievement correlations for each treatment group were examined separately, those for treatments 2 and 3 showed many high correlations (for  $T_2$  37 of 45 correlations were significant, for  $T_3$  30 of 45 were significant). Treatment 1 scores did not correlate well with achievement measures, however (for  $T_1$  2 of 45 were significant). Much of this difference can be attributed to the spuriously high seriation results that appeared to be caused by rote understanding of seriation in this group. However, this result confuses the relationship between achievement and seriation somewhat.

### Conclusions

There appears to be a correlation between seriation task scores and achievement in the more traditional first grade subjects of reading and math. While the administration of treatments in this study tends to cloud the relationship, the correlations across all treatments and for the placebo ( $T_3$ ) treatment indicate a strong link between the two sets of tasks. It might be overoptimistic to expect that reading and math achievement differences could be attributable to a treatment administered in four 15 minute sessions some three months distant from the posttest. It is not too optimistic to hypothesize that reading and math achievement differences might occur with a treatment extended over a longer period of time, however. As Waller (1977) states ". . . reading requires competence in seriation," in that the order of letters, words and sentences is important to comprehension of a written passage.

Future research should assess the causal relationship between training and practice on seriation tasks and improvement of reading and mathematics skills among young children.

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## PROCESSES OF ELEMENTARY SCHOOL SCIENCE

### TEACHING: AN OBSERVATIONAL STUDY

Charles W. Anderson

Michigan State University  
East Lansing, MI 48824

James P. Barufaldi

University of Texas  
Austin, TX 76010

Most professional science educators advocate that elementary school science should be taught by using "inquiry-oriented" techniques, in which textbooks and factual content in favor of giving children first-hand experience with manipulative materials and scientific inquiry. Many elementary school teachers, however, seem to have difficulty in teaching this way, and attempts to implement the "new" science programs have often been disappointing (Ost, 1976; Weiss, 1978; Fitch and Fisher, 1979).

Although the fact that the new curricula have been difficult to implement is now fairly well documented, the causes of that difficulty are less well established. In particular, information available from science education research describing what actually happens when elementary school teachers teach science lessons is limited in quantity and in quality.

This study was, therefore, designed with the following objectives:

- 1) to design and use an observation system that provides detailed information about events during elementary school science lessons; and,
- 2) to evaluate the success of the teaching strategies used in the observed lessons.

The study was naturalistic in design. An observation system was developed that provided detailed descriptions of elementary school science classes. A single observer described 57 elementary school science lessons as they were taught by regular classroom teachers.



All of the 22 second, third, fourth, and fifth grade teachers who taught science in a small suburban school district were observed. Some of the teachers used Science Curriculum Improvement (SCIS) materials. Others relied on textbooks and a variety of locally produced materials. The success of each lesson was evaluated by means of three different short-term outcome measures: The teacher and the observer each rated the success of the lesson, and the average proportion of students off task during the lesson was calculated as a behavioral indicator of the success of the lesson.

The results of the study emphasized the importance of the limitations under which elementary school teachers must operate. The teachers were typical of many elementary school teachers in that they had very limited time to prepare for teaching science lessons, and in that their knowledge of science content and processes was also quite limited.

Under these conditions, the teachers preferred methods and materials that:

- 1) did not demand excessive preparation time;
- 2) simplified the task of classroom management; and,
- 3) were not likely to place unexpected demands on the teacher's knowledge of science.

When they attempted to use methods or materials that did not meet these conditions, the lessons they taught tended to be less successful.

The significance of this study lies in two areas. First, the observational techniques developed for this study can be used for the analysis of classroom teaching in science. Second, the results raise serious questions about the practicality of the methods and practices commonly recommended by science educators. For example, lessons involving "inquiry-oriented" discussions and manipulative science materials are often difficult to teach, demanding time and knowledge that exceeds that of many elementary school teachers.

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FACTORS EFFECTING THE USE OF THE SCHOOL GROUNDS  
FOR CLASS TIME SCIENCE INSTRUCTIONAL ACTIVITIES

Chester G. Hall, III  
Emmett L. Wright

University of Maryland  
College Park, MD 20742

Objectives and Rationale

Objectives were to determine for class time secondary science instructional activities:

- 1) the extent of use of school ground;
- 2) the factors effecting this use; and,
- 3) the critical factors limiting this use.

The extent and nature of factors effecting use of the school ground must be determined in order for educators who intend to increase the utilization of this instructional resource, to have a factual basis to enhance positive factors and minimize negative factors.

Methodology and Design

- 1) A fully piloted survey instrument was developed to determine factors effecting use of the school grounds for class time science instructional activities.
- 2) Data were collected at a secondary science teacher inservice meeting of a large public school system.
- 3) Data were analyzed, classified, and summarized.

Instruments and Data

Respondents considered only school ground science instructional activities occurring during class time.

Part A of the instrument included population and frequency of use data. Part B utilized a Likert-type scale in which 21 factors were independently rated as to the extent each effected the use of the school grounds for class time science instructional activities. In Part C the respondents cited and briefly discussed the major critical factors limiting use of the school grounds for class time science instructional activities. Data were collected separately by grade level taught. Mean ratings and standard deviations were calculated for each factor with individual grade level and composite data.

### Results and Conclusions

Only the results from composite data are reported here. Similar general findings resulted from analysis of the specific grade level data, but curricular and developmental differences were reflected.

The following frequencies of use of school grounds for class time science instructional activities were reported:

| <u>Frequency/Semester</u> | <u>% Frequency Reporting</u> |
|---------------------------|------------------------------|
| 0-1                       | 53.5                         |
| 2-4                       | 30.8                         |
| 5-8                       | 11.0                         |
| 9-11                      | 2.3                          |
| > 11                      | 2.3                          |

It is evident that there is infrequent use of the school grounds for class time science instructional activities.

Based on analysis of means and standard deviations, the factors were ranked in decreasing order of encouragement for school ground class time science instructional activities.

Four factors were found to be in the "strongly encouraging" range: student preference, teacher's background knowledge, teacher's personal preference, and teacher confidence. These factors related to human motivation, indicating considerable interest by both teachers and students in the use of the school grounds for class time science instructional activities.

Five factors were rated in the "slightly encouraging to neutral" range: weather/climate, preparation/preplanning, administration policy, school site, and curriculum restrictions. Another set of five factors were rated in the "neutral to slightly discouraging" range: materials/supplies, parent's concerns, other teachers' reactions, allergies/medical problems, and security. These two sets include many factors often surmized to be discouraging, but were found in this study to be relatively neutral.

Four factors were found in the "moderately discouraging" range: safety considerations, space conflicts with physical education classes, length of class time, and liability of teacher. The last set of factors was rated "strongly discouraging": student discipline, maturity of students, and class size.

The "moderately discouraging" and "strongly discouraging" factors were sufficiently severe in their effects to overcome the "encouraging" factors and resulted in the low frequencies of use reported. Student discipline and class size were also the major critical factors limiting class time use of school ground cited in Part C. These two factors should serve as areas of focus for educators concerned with strategies to enhance the utilization of school ground resources for science instruction.

THE ROLE OF INVESTIGATION AND DISCUSSION IN CHILDREN'S  
CONCEPTUAL DEVELOPMENT IN SCIENCE

Eugene F. Trainor

39 Robbins Street  
Acton, MA 01720

In this study the oral statements of four randomly selected groups of children involved in two science activities were examined for conceptual growth. The treatment groups consisted of two groups, 15 subjects each. A fifth randomly selected group functioned as the control group. Two methods of instruction, referred to as treatments in this study, were used.

In Treatment I (investigation-colloquium method) two of the groups of fifth grade children worked together manipulating conceptually provocative, concrete science materials. The subjects discussed their observations and the meaning of their observations with each other and with the instructor who directed the discussion according to the Lansdown method. In Treatment II (investigation-nondirected discussion method) the other two experimental groups of children manipulated the identical science materials as used in Treatment I. Students in Treatment I described their observations in a discussion in which the instructor's role was nondirective and passive. A fifth group, the control group, was exposed to the two science units, and the classroom teacher, in place of the instructor, was present during the discussion period. The teacher functioned in a passive and nondirective manner as generally suggested by the Elementary Science Study teacher's manual. All students taking part in the study were examined for conceptual growth by a classification of their oral statements according to criteria established by Lansdown (1971). To insure the accuracy and fidelity of each student's oral statements for classification, recordings of the discussion were made on magnetic tape.

The members of the classes in the study were tested to determine their intelligence quotient through the use of the Otis-Lennon Mental Ability Test. No significant difference in mean intelligence quotients was found between the test classes. No significant differences existed between treatment groups nor was the control group's mean I.Q. significantly different from the others.



A protocol defined the functions followed by the instructor and stated the type and quantity of materials to be used in each of the five sessions of each unit. Eight judges were trained to use a scoring scheme to classify the subjects' statements based on the Lansdown schema. Over 700 statements were categorized involving more than 5000 judges' decisions. The statements were first sorted according to Vygotsky levels where only two levels Complex and Preconcept, were involved. The judges also analyzed each communication for Lansdown characteristics, that is, Compared statements, Analogies, External Generalized, and Hidden Generalized statements.

When the treatments, investigation-colloquium, investigation-nondirective discussion, and control were compared, the results were significant. The children involved in the discovery-colloquium treatment uttered 458 statements; those involved in the discovery-nondirective approach spoke 191 statements and the 15 subject control group stated 120 statements. Of these statements, 30.1 percent of the Treatment I subjects (discovery-colloquium) statements were at Vygotsky's higher level - Preconcept statements; 17.8 percent of the Treatment II (discovery-nondirective approach) were at this level; and 14.2 of the control group statements were judged to be preconcept.

When the expected growth in thinking represented in the increased use of preconcept statements did not occur in the sequentially developed lessons, it was suggested that more time be given to this phase. This conclusion may in part be supported by the fact that judges assigned twice as many statements to the preconcept category in the second half of discussions. Complex statements were classified according to Lansdown characteristics associated with complex statements, such as comparisons, and external generalizations. The preconcept statements were often also classified as analogies, hidden generalizations, and models. More model statements were classified as preconcept than as complex statements suggesting models (explanations) were more often a higher order of thinking.

The implications for education are two-fold:

- 1) Investigation discovery lessons should be followed by a structured discussion in which each child is encouraged to state his/her observations and procedures and teachers should raise conflicting observations. Appropriate science vocabulary should be used where children already understand the phenomena and, finally, children should be encouraged to explain why the results of their investigation occurred the way they did.
- 2) Lansdown has provided a formative evaluation procedure which needs to be studied in future research to test and define more stringently the categories of evaluation.



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A CROSS AGE STUDY OF HOW CHILDREN IN  
ELEMENTARY SCHOOL CONCEPTUALIZE TIME

Kip Ault

Cornell University  
Ithaca, NY 14850

The purpose of this study was to characterize the diversity and range in the elementary grades of children's concepts about time. The investigation was undertaken to determine whether children's concepts about time should be considered a potential "barrier" to their ability to grasp the meaning of time as used in scientific explanations.

Thirty-two children, eight per grade level from grades K, 2, 4, and 6 were interviewed in response to a series of time-concept tasks. The first set, Piagetian in design, required children to apply an understanding of time to an observed pair of motions (two metal balls descending at different speeds). Children were asked, "Did they start at the same time? Did they stop at the same time? Did one move for more time than the other? If the opposite end were lifted, would one ball return to the start before the other?" The children also made diagrams of relative position at regular intervals of time. These diagrams were separated, shuffled and used to reconstruct the motions as a series of positions.

In the second set of tasks the children commented on the appropriateness of several series of sounds and sights for time measurement: Tape recorded dog barks, frog-peeps, phone rings and popcorn as well as burning candles and pendulum motion. Children ate a pair of peanuts, timing the first with telephone rings and the second with busy signals. Children also responded to questions about the passing of time when no clocks are available and offered examples of events which take seconds, minutes, weeks, years, and many years to happen.

Analysis of the transcribed interviews revealed that children in kindergarten and grade two tended to equate more time with more distance, speed or effort. Not until the fourth grade interviews were any subjects encountered who could apply the principle of time conservation as a logical predictor of "return time" when the motion of the two balls was reversed.

Responses to questions about the passing of time and its measurement with either a series of sounds or divisions of a continuous motion revealed some understanding of the principle of equal intervals as early as second grade. Many children were categorized as "clock-bound" -- as holding the notion that time exists as something real and absolute, that its discovery was accomplished by the people who first "found out" that time goes by in seconds, minutes, etc. and that these units are related to each other in a predictable fashion.

Several children grasped the relational principle of time measurement: They were comfortable speaking of durations as the number of reference events an activity took, ranking series of physical events as good or bad for time measurement, and deriving a standard unit from seemingly irregular sound and sight sequences. The successes and frustrations the children had with these activities indicated a very elemental association between time and number, particularly counting.

The responses to the two sets of activities revealed that the meanings children ascribed to time and the understandings they had of its use varied greatly. Even individuals held several seemingly incompatible notions about time simultaneously; yet some of these notions were as sophisticated as any expected from adults.

The many levels of understanding and novel meanings described in this paper suggest:

- 1) a high potential for the assimilation of scientific time concepts by many elementary students;
- 2) an equally high potential for confusion when scientific time concepts are introduced in the absence of relevant prior understanding; and,
- 3) a high risk that children uninitiated to concepts of time in science will elaborate their own impressions of time towards conclusions in conflict with efforts to grasp scientific explanations.

THE EFFECTS OF DIAGNOSTIC PRESCRIPTIVE INSTRUCTION  
ON SCIENCE ACHIEVEMENT: A META-ANALYSIS

P. Ann Miller  
Russell H. Yeany

University of Georgia  
Athens, GA 30602

In recent years, the effect of diagnostic prescriptive (remedial) instruction on learning has been the focus of many studies. The purpose of this paper is to review and analyze the results of experimental studies based on diagnostic prescriptive instruction as it effects science achievement. The relatively new statistical analysis procedure of meta-analysis lends itself well to this task.

Meta-analysis techniques are used for condensing and synthesizing the results of a multiple set of empirical studies into an interpretable form. These procedures are quickly gaining favor as a means of making sense of the varied results usually present when one examines numerous studies on a single topic. Meta-analysis techniques are used to calculate a statistic referred to as "effect size." This value is based upon the group means and standard deviations from results of individual studies.

#### Data Collection

An ERIC search identified a body of studies on diagnostic prescriptive instruction and science achievement which examined a total of 30 dependent variables. Subjects used in the combined studies numbered over 500 college, high and middle school students.

#### Procedure

Means for treatment groups were established and standard deviations determined for each study from the reported data. From this information, an "effect size" was calculated on each dependent variable.

Data were organized by categorizing all treatments into one of three types:

- 1) Control, no diagnosis and no prescription;
- 2) Treatment I, diagnosis and no prescription; and,
- 3) Treatment II, diagnosis and prescription or remediation.

This yielded a total 21 Treatment I and 32 Treatment II effect sizes. A mean effect size was then calculated for each treatment.

#### Results of Data Analysis

Based on the 30 different measures of achievement and attitude the mean effect sizes for each category were: .50 for the Treatment I and .54 for the Treatment II.

#### Conclusions

The results of meta-analysis indicate that diagnostic prescriptive instruction significantly and positively influences science achievement. But, there is no clear indication from the body of research that the use of prescription or remediation in addition to diagnosis brings about a significant increase in achievement which is worth the additional effort.

An examination of sub-group of the studies did reveal that prolonged participation in remediation treatment increased the effect size of this treatment type.



A META-ANALYSIS OF THE RELATIONSHIP BETWEEN SCIENCE  
ATTITUDES AND ACHIEVEMENT IN SECONDARY SCHOOL SCIENCE

Victor L. Willson

Texas A & M University  
College Station, TX 77843

Secondary science education is in the position of knowing more than it can tell in the area of attitudinal relation to achievement. A large body of literature has accumulated in the area, often the byproduct of validation of new measures of science attitude. Reviews on science attitude have been written (Aiken and Aiken, 1969; Fraser, 1977) but no systematic study of the attitude-achievement relationship made. This paper reports results of a formal statistical review of attitude-achievement correlations in secondary science.

Glass (1977) has proposed a statistical model for the review of research results, which he terms meta-analysis. In meta-analysis the dependent variable is the individual statistic reported for a study in the area. For this study it is the individual correlation coefficient or coefficients reported in science education articles. For each coefficient relevant independent variables are coded such as student grade level(s), sex, ability level, science course currently enroll in, sample size, year of study, and experimental manipulation. These become independent variables in regression analysis to determine important contributors to the outcome being examined.

Uguroglu and Walberg (1979) reported a meta-analysis of achievement-attitude correlations on a sample of studies which spanned all of education. They were able to predict about 40% of variance in the magnitude of correlation. They reported grade level was a significant predictor. Their study included only a few science correlations and is not sufficiently detailed for any generalizability concerning science education.

For the current research the domain for review is restricted to secondary science. Within this domain junior and senior high levels will be examined separately as well as jointly. The restriction to secondary levels is based on a logical distinction: The relationship between attitude and achievement has a different conceptual meaning in secondary science from that in elementary.

Science course work is formalized in secondary schools and students self-select in upper grades. There is no compelling reason to merge elementary and secondary correlations, and the merger might well disguise the true magnitude of effect at either level.

The process of review had three parts. The first was a standard library search. Both ERIC and a branching search from known articles was utilized for this. The second part involved coding each study. Each correlation coefficient reported became an individual unit of analysis. With each coefficient was joined all relevant, reported independent variables in the study. This coding was subject to error so that a random sample was selected for recoding so as to estimate coder reliability. The third part of the review consisted of computerized statistical analysis of relationship between the independent variables and the attitude-achievement correlations. This involved multiple regression, discriminant analysis, or ANOVA, depending on the type of independent variables coded.

The meta-analysis provided a systematic review of concomitants at the secondary school level to correlation between attitude and achievement. These procedures were carried out to uncover areas in which no research has been performed and areas where results are unclear or contradictory.

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SCIENCE MANIPULATIVES: EFFECTS ON DEVELOPMENT  
OF SPATIAL CONCEPTUAL ABILITY

Herbert G. Cohen

Arizona State University  
Tempe, AZ 85281

The primary purpose of this study is to investigate what effects "hands-on" science has on the development of selected spatial conceptual abilities assessed using Piagetian-type measures and a science process measure.

Two propositions underlie the rationale for this first component. First is the notion that higher levels of spatial conceptual ability, for example, that of projective space allows a child to develop a better understanding of science processes. Studies indicate that a large proportion of elementary age children and a smaller proportion, but still substantial member of junior high age children lack the intellectual structures to fully comprehend spatial concepts in their environment.

A second proposition which is that in order to gain knowledge and develop more highly refined spatial abilities a student must act on objects -- that is, displace, connect, combine, take apart and reassemble objects.

Combining these two propositions yields the notion that for a child to develop higher levels of spatial ability the child must have access to materials and be given the opportunity to manipulate the objects. The resulting conceptual abilities, plus other forms of knowledge derived from manipulation of materials should lead to higher levels of understanding with respect to science process ability.

A secondary purpose of this study is to assess what effects locus of control has on the development of spatial conceptual ability. It is posited that children with an internal locus of control will interact with materials to a higher degree than those with an external locus of control and that this higher degree of interaction will lead to a greater development of spatial conceptual abilities as well as a greater acquisition of science processes.

To date little empirical evidence has been proffered in order to establish beyond a doubt whether or not the manipulation of objects actually facilitates the development of cognitive structure and acquisition of science processes. Furthermore, conflicting research findings indicate that "hands-on" science might be important in some instances and appears to make no difference in other instances.

#### Design and Procedures

The experimental design is posttest only control group. The Nowicki-Strickland Locus of Control Measure was administered to the pupils of two fifth grade classes. Of those subjects determined to exhibit an internal locus of control one-half were randomly assigned to the experimental group and the remaining half assigned to the control group. A similar procedure was followed to equally distribute those subjects exhibiting an external locus of control.

The experimental group received instruction using SCIIS materials while the control group's instruction was designed around a textbook - Learning Science (Renner, 1977). Selected sections from Level 5, Energy Sources from the SCIIS program and Level 5, Action from the Learning Science textbook series were used. Instruction with the SCIIS materials was characterized by student-directed lessons with teacher guidance with manipulation of concrete materials. In contrast, the textbook oriented class was teacher-directed, and the focus was on written rather than manipulative exercises. In both situations the instructor exhibited similar behaviors: verbal behavior included the use of divergent, higher level questions, appropriate wait time, and the offering of alternative activities for pupils to pursue.

The data from the locus of control measure, the science process measure and the Piagetian-type tasks were of such a nature to lend themselves to analysis using non-parametric statistical procedures.

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THE EFFECTS OF ECO-CULTURAL FACTORS IN OPERATIONAL  
THOUGHT AMONG SOME NIGERIAN ADOLESCENTS

O. J. Ehindero

University of Ife  
Ile-Ife, Nigeria

Objectives and Rationale

Within the conceptual framework of intellectual development, Inhelder and Piaget (1958) and Piaget (1971), have proposed a model linking individual's intellectual development with socio-cultural, experiential, neurological and equilibration factors. Although several studies have validated the influences of some of these factors in intellectual growth (Bovet, 1974; Waite, 1974), a great deal still has not been known about the possible effects of certain eco-cultural functionalism on the development of operational thought among non-Western subjects. In fact, Piaget (1976) suggested that "it is quite possible (and it is the impression given by the known ethnographic literature), that in numerous cultures, adult thinking does not proceed beyond the level of concrete operations and does not reach that of propositional operations, elaborated between 12 and 15 years in our cultures" (p. 208).

The purpose of the present study is therefore to investigate the effects of certain eco-cultural factors on operational thought. Is it possible that individual performances on certain Piagetian tasks is influenced by certain ecological demands and adaptational requirements placed on such individuals?

It is hypothesized that individuals inhabiting ecologies where nomadism and hunting are the dominant modes of sustenance and who live in thinly populated areas with little or no contact with Western type culture, should develop perceptual and spatial skills adapted to the eco-cultural demands of nomadic and hunting life styles. Also for individuals who live in a settled area and who are agriculturalists with a fairly thick population and living in communities whos contact with Western-type culture is high, the adaptational requirements for nomadism and hunting will diminish in importance.

Inherent in this hypothesis is the expectation that nomadic and hunting life-styles demand spatial skills and also that such



individuals, since their environment, and therefore their eco-cultural demands, are relatively few and simple, will have little need for complex and sophisticated intellectual strategies as symbolized by performance on certain Piagetian formal tasks. A corollary to this argument is that individuals living in relatively complex ecologies where social transmission is more, varied and complex, the need to be formal operational is greater and almost imperative. Hence, in each of these two ecological continuum, there are likely to be cultural aids, buffers and amplifiers which mediate between adaptational desiderata and operationalism.

#### Methodology and Design

To investigate this hypothesis, four spatial tasks (Tangrams, topological spatial relation, location of topological position, and coordinate reference system) and four formal operational tasks (proportionality, control of variables, combinatorial analysis, and propositional logic) were administered to 80 subjects. The Ss were in the following categories: Schooled nomadic Fulani's, 20 Ss; unschooled nomadic Fulani's, 20 Ss; schooled settled agriculturalists, 20 Ss; unschooled settled agriculturalists, 20 Ss. Their ages ranged from 15 to 19 years with a mean of 17.6 years.

A 2x2 ANOVA and the Scheffé method for post-hoc comparison of group means were used to analyze the data. Of interest were the performances of both groups of Ss on spatial and formal task when analyzed separately.

#### Results and Conclusions

The results revealed an overall significant effect ( $p \leq .01$ ) of culture and schooling on performance on Piagetian tasks. The interaction effect was not significant. Is it possible that certain experiences provided in Western-styled schools have mediating effects to potentially offset the eco-cultural and social constraints on intellectual development? This, and the effects of factors, (particularly the nature and possible roles of the science programs provided in the Ss's schools) on intellectual development are widely discussed. The possible roles of the scientific community (in a rapidly developing Nigeria) in the development of formal and rational thought are discussed in addition to an in-depth discussion of implications to science teaching and scientific literacy.

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## THE DIFFERENTIATION OF SPATIAL ABILITY AND ANALYTIC ABILITY

William J. Doody

Syracuse University  
Syracuse, NY 13210

### Objectives and Rationale

In a previous study (Doody, 1979) of sex related cognitive differences and performance in science, a sex difference was discovered which required further investigation. Specifically, it was found that whereas the product moment correlations between Spatial Ability and Performance (in three units of study) were .81, .78, and .75 for boys, they were .29, .50, and .27 for girls. These results were particularly intriguing in view of the fact that no sex differences in Spatial Ability or Performance were found. These results suggest that, although no sex difference existed in each variable, a sex difference in the interdependence (correlation) of the variables did exist. Spatial Ability was a significant predictor of performance for boys, but not for girls.

The objectives of this followup investigation were first to examine the dependence of Spatial Ability (SA) upon:

- 1) Perceptual Regulation;
- 2) Cognitive Regulation; and,
- 3) Problem Solving.

Second, to determine whether a sex difference exists in these variables, for the selected sample; and, third, to determine the dependency of specific types of problem solving upon Perceptual Regulation, Cognitive Regulation, and Spatial Ability.

### Sample and Measures

As in the previous study, a sample of tenth grade Regents Biology students was selected from an urban high school (30 boys, 30 girls). The Group Embedded Figures Test (GEFT) was administered to all subjects to determine Spatial Ability. Perceptual Regulation and Cognitive Regulation of mental imagery were assessed by proceedings derived from Matalon's and Tyborowska's techniques (Mental Imagery in the Child, Piaget, 1971). Problem solving

was defined by performance on a problem set developed for this study; the problems were developed to the specification that each of four problems had similar content but required distinct skills for satisfactory completion.

#### Methodology and Design

Groups of four subjects (two boys and two girls) were administered the above tasks in the following order:

- 1) Placebo (to diminish testing effect);
- 2) Perceptual Regulation;
- 3) Cognitive Regulation;
- 4) Spatial Ability; and,
- 5) Problem Solving.

Three experimenters administered the tasks; experimenter #1 administered the Placebo, Perceptual Regulation and Cognitive Regulation tasks; experimenter #2 administered the Spatial Ability task; experimenter #3 administered the Problem Set. Factor analysis and multiple regression were used in data analysis.

#### Results

Individual differences in performance upon the measure of Spatial Ability were localized; while Spatial Ability score was dependent upon Perceptual Regulation for one subgroup for whom Perceptual Regulation was decisive in determining Spatial Ability, Problem Solving was not correlated with Spatial Ability to the same extent as with the subgroup for whom Cognitive Regulation was decisive in determining Spatial Ability.

#### Conclusions

These results are in keeping with the Constructivist model of intelligence as opposed to the Empirical model of intelligence. The former emphasizes the dynamic nature of knowledge (knowledge is the equilibrium between an organizing subject and a resisting object) whereas the latter emphasizes the persistent nature of knowledge (knowledge is the consequence of the subjects organizing truth which abides in nature). The Constructivist's model allows for the existence of individual differences in Perceptual Regulation without a consequent difference in knowledge; i.e. an individual may exhibit a deficit in Perceptual Regulation and problem solving of spatial problems is likely. The distinctive characteristics of these positions carry significant implications towards providing equal opportunity in science education for girls.

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